The Socio-Demographic Characteristics of Diabetes, Hypertension, and Cardiovascular Disease Risk in India

THE SOCIO-DEMOGRAPHIC CHARACTERISTICS OF DIABETES, HYPERTENSION, AND CARDIOVASCULAR DISEASE RISK IN INDIA

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Abstract

Background:

Cardiovascular disease (CVD) is the leading cause of mortality in India. Yet, the evidence is sparse on how diabetes, hypertension, and predicted CVD risk vary between population groups in the country. This dissertation aimed to determine how the prevalence of diabetes, hypertension, and predicted CVD risk in India varies by state, rural-urban location, and individual-level socio-demographic characteristics.

Methods:

Data were pooled from the Annual Health Survey (2012-2013) and the District-Level Household Survey-4 (2012-2014). Diabetes was defined as a plasma glucose ≥126 mg/dl if fasted or ≥200 mg/dl if non-fasted, and hypertension as a systolic blood pressure (BP) ≥140mmHg or a diastolic BP ≥90mmHg. Predicted 10-year CVD risk was calculated for each participant aged 30 to 74 years using the Framingham risk score, and dichotomized into high (≥30%) or low risk (<30%).

Results:

1,320,555 adults aged ≥18 years were included in the diabetes and hypertension analysis, and 797,932 adults aged 30 to 74 years in the CVD risk analysis. The crude prevalence of diabetes, hypertension, and high CVD risk was 7.3% (7.1 - 7.4), 23.6% (23.4 – 23.7), and 14.6% (14.4 – 14.8) among females, respectively, and 7.8% (7.6 - 8.0), 27.3% (27.1 – 27.5), and 31.7% (31.4 –

32.0) among males, respectively. There was substantial variation in the prevalence of each outcome among states. Being in the richest compared to the poorest household wealth quintile was associated with only a modestly higher probability of diabetes (rural: 2.8 [2.5 - 3.1] percentage points; and urban: 3.5 [3.0 - 3.9] percentage points) and hypertension (rural: 4.2 [3.7 - 4.6] percentage points; and urban: 3.0 [2.4 - 3.7] percentage points). The differences in the probability of all conditions by educational category were generally small.

Conclusion:

The prevalence of diabetes and hypertension in India is high, and predicted CVD risk was approximately twice as high as has been estimated for the United States. The important variation in the prevalence of each outcome by state and socio-demographic characteristics can inform planning and resource allocation as well as effective targeting of CVD programs to reach those most in need.

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Introduction

Cardiovascular disease (CVD) is the leading cause of mortality worldwide, including in low- and middle-income countries (LMICs).[1] India is estimated to contribute almost one fifth (18.9%) of the world's CVD burden as measured by disability-adjusted life years (DALYs).[2] Importantly, extant evidence suggests that South Asians are predisposed to developing CVD.[3-9] South Asian migrants have 1.5-2.0 times the prevalence of coronary artery disease compared to age- and sex-matched white Europeans,[3-5] and are estimated to develop coronary artery disease six to ten years earlier than white Europeans.[6] Further, South Asian immigrants in Western populations have a higher prevalence of type 2 diabetes, and tend to develop type 2 diabetes at a younger age and lower body mass index (BMI), than their white European counterparts.[7-9] Given the Indian population's predisposition to developing CVD and diabetes, India's huge population size,[10] and the country's rising living standards,[11] CVD and its risk factors in India are critically important to not just India, but also for global health.

In addition to its large burden on health, CVD is also a major cause of impoverishing household healthcare expenditures in LMICs.[12] In India, which has the highest proportion of total health expenditures from out-of-pocket payments of any 'BRICS' (Brazil, Russia, India, China, and South Africa) country and where only 15% of the population has health insurance,[13,14] Jan et al. found that 59% of uninsured and 20% of insured individuals who had been hospitalized for acute coronary syndrome experienced catastrophic healthcare expenditure (defined as treatment costs greater than 30% of annual household income).[15] By diverting savings from capital investments to healthcare consumption and by reducing labor supply, CVD also has a large negative impact

on economic growth. For example, Bloom et al. estimated that CVD will reduce India's economic output by $2.17 trillion between 2012 and 2030.[16]

Although the cardiovascular consequences of hypertension and diabetes – such as myocardial infarction and stroke – are costly to treat, the management of hypertension and diabetes are less costly and less complex, providing an opportunity to effectively address these conditions and mitigate adverse outcomes in India and similar settings. For instance, many effective anti-hypertensive and anti-diabetic medications, as well as insulin, are generic and have relatively low production costs.[17] However, the existing evidence suggests that less than half of Indian adults with diabetes or hypertension have been diagnosed.[18,19] There is, therefore, a clear need for expansion of CVD prevention, screening, and treatment services in India.

Understanding how CVD risk and the prevalence of CVD risk factors vary among population groups is essential for health system planning, and to target resources for prevention, screening, and treatment interventions most effectively and efficiently. However, oftentimes evidence on CVD risk in India is restricted to healthcare facility-based samples or small population-based cohorts in specific locales. Hence, there is an important knowledge gap and need for evidence underpinned by analyses, which utilize large-scale nationally representative surveys. In pooling data from two large household surveys in India, which are jointly representative for the entire country, and using rigorous methods of analysis, I aim to address critical knowledge gaps in relation to CVD risk in India. These analyses are important empirical contributions to the evidence base to help inform policy and practice in India to more effectively address CVD.

Specifically, my aims for each of the three dissertation papers and the contributions I will make are outlined below.

Paper 1 aims to provide a new diabetes prevalence estimate for India, and to determine how diabetes prevalence in the country varies by state, rural versus urban residence, and individual-level socio-demographic characteristics. A particular focus of this analysis is the relationship between diabetes and household wealth in India with a view towards examining empirically the frequently held assumption that diabetes is mainly restricted to wealthier urban strata of Indian society. This paper uses capillary glucose measurements in non-pregnant adults aged 18 years and older. While the recently published ICMR-INDIAB study addresses some of these aims,[19] there is still no empirical diabetes prevalence estimate for India that relies on nationally representative data. This study will fill this important knowledge gap by using data from a much larger set of states (and a larger sample size within each state) than INDIAB. Methodologically, this study will extend the INDIAB study by disaggregating socioeconomic status into household wealth quintile and educational attainment (unlike the composite indices used in INDIAB), and employing district-level fixed effects regressions, thereby 'filtering out' observed and unobserved confounders at the district level.

To date, there has not been a study of hypertension in India, and its variation among population groups, that uses nationally representative data. Paper 2 aims to fill this important knowledge gap by determining the prevalence of hypertension nationally as well as by state. Methodologically, this study also relies on district-level fixed effects regressions but, in addition, examines how

rural-urban differences in hypertension prevalence vary with a district's standard of living. This paper uses blood pressure measurements in non-pregnant adults aged 18 years and older.

Paper 3 aims to fill the acute knowledge gap that despite existing analyses of CVD risk factors in India, no population-based study in the country has examined the predicted risk of a CVD event as an outcome. Such an analysis is crucial as CVD is an important endpoint of interest to policy makers, and its variation among population groups is unclear given that CVD risk factors likely vary differently along socio-economic and demographic gradients. Specifically, this study aims to determine the proportion of India's population, which has a 10-year predicted risk of a CVD event of 30% or more. I chose this threshold because it is used by the World Health Organization (WHO) in its Global NCD targets to define who is eligible for counselling and/or medication to reduce CVD risk.[20] This risk was calculated using four different commonly used CVD risk calculators that do not require blood lipid measurements: the Framingham Risk Score,[21] Globorisk,[22] the Harvard-NHANES score,[23] and WHO-ISH.[24] The natural logarithm of CVD risk was regressed onto rural-urban residence and individual-level socio-demographic characteristics. This analysis was restricted to adults aged 30 to 74 years, which is the age range for which commonly used CVD risk calculators have generally been validated.

Jointly, these three papers will provide a comprehensive assessment of the socio-demographic pattern of CVD risk in India. Specifically, as explained above, papers 1 and 2 fill important knowledge gaps with regards to the prevalence and socio-demographic variation of diabetes and hypertension in India. In contrast, the socio-demographic patterns of smoking and Body Mass Index (BMI) in India are well studied.[25,26] By creating a composite CVD risk estimate using

participants' age, sex, smoking status, BMI, diabetes status, and systolic blood pressure, paper 3 can thus be viewed as combining evidence from papers 1 and 2 with evidence on these comparatively better-studied CVD risk factors to yield a full picture of CVD risk in India.

The major contributions of these three papers to existing studies of cardiovascular risk factors in India are that i) the dataset is nationally representative having collected data in virtually all 29 states and seven Union Territories of India (as compared to the INDIAB study,[19] which has thus far published diabetes estimates for only 15 states); ii) unlike the INDIAB study, which sampled only around 4,000 participants per state, both AHS and DLHS-4 have aimed to achieve a representative sample of participants from each district in India (sampling a mean of approximately 3,000 individuals per district); iii) it examines hypertension and diabetes as well as composite cardiovascular disease risk in the same dataset (as compared to the INDIAB study, for example, which focused on diabetes); and iv) throughout this dissertation, I use regressions with fixed effects at the level of the primary sampling unit, which filters out area-level effects (e.g., the local socio-economic environment) on the outcome, rather than using pooled regressions (as the INDIAB study has done), which is less suited for identifying individual-level (as opposed to area-level) effects on the outcome.

The main aim of all three papers in this study is to examine how the outcome (diabetes, hypertension, and predicted CVD risk) varies within India. In Figure 0.1, I have laid out the different levels at which variation in the outcome was examined in this dissertation. Papers 1 and 2 of this dissertation are in press at *JAMA Internal Medicine*.[27]

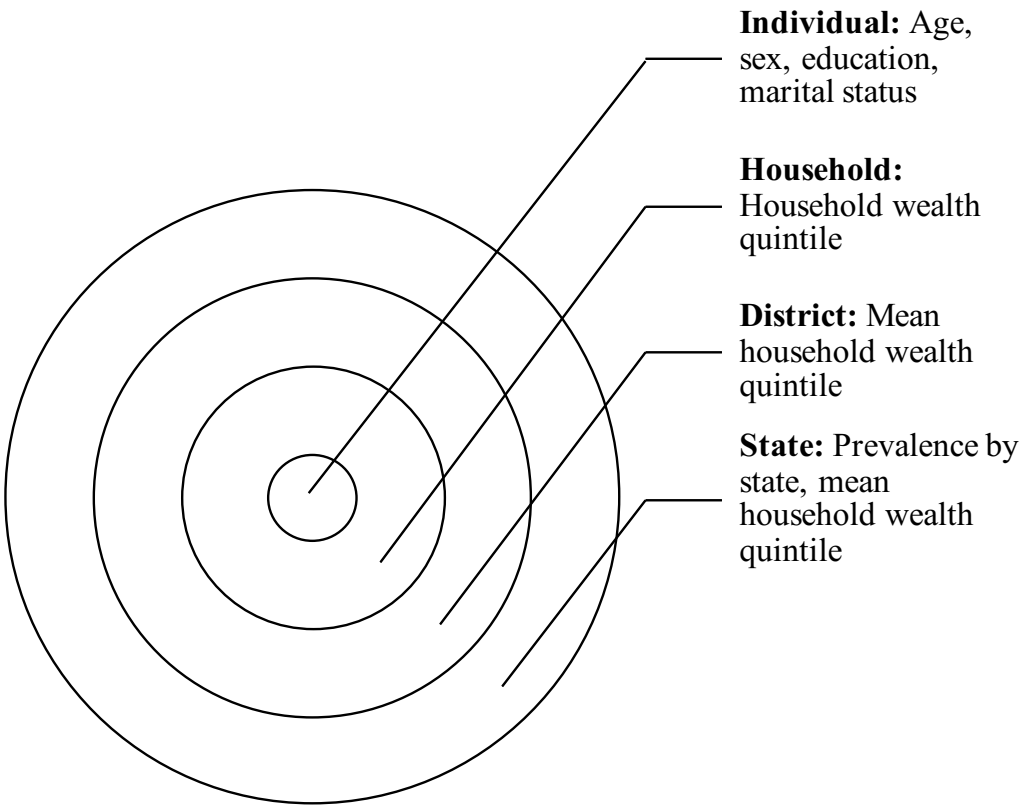


Figure 0.1 Socio-demographic variables examined in this dissertation.

PAPER 1

The socio-demographic characteristics of diabetes in India: Evidence from a nationally representative sample of 1.3 million adults

Abstract

Importance: The prevalence of diabetes in India is increasing. Yet, there has not been a nationally representative study to ascertain how prevalence varies among population groups in the country.

Objective: To determine how diabetes prevalence varies by state and adults' socio-demographic characteristics.

Design: Cross-sectional nationally representative study carried out between 2012 and 2014.

Setting: Population-based.

Participants: 1,320,555 adults with a capillary glucose measurement

Exposures: State, district, rural versus urban location, age, sex, household wealth, educational attainment, and marital status.

Main measure: Diabetes (plasma glucose ≥126 mg/dl if fasted or ≥200 mg/dl if non-fasted)

Results: The crude prevalence of diabetes was 7.5% (95% CI, 7.3 - 7.7) ranging from 2.3% (95% CI, 2.0 - 2.8) among females in Madhya Pradesh to 17.9% (95% CI, 15.4 - 20.7) among males in Goa. Being in the richest compared to the poorest household wealth quintile was associated with only a modestly higher probability of diabetes (rural: 2.81 percentage points;

95% CI, 2.53 - 3.08 and urban: 3.47; 95% CI, 3.03 - 3.91). While household wealth quintile and living in an urban area were both positively associated with diabetes, the prevalence among those in the poorest quintile in rural areas aged 40 years and older was nonetheless high (5.9% [95% CI, 5.5 - 6.2]). The differences in the probability of diabetes by educational category were generally small (≤1 percentage point).

Conclusions: Diabetes prevalence in India was lower than previously estimated. Nonetheless, diabetes is common in middle and older age groups across all geographies and socio-demographic groups. Knowledge of variations in prevalence will help inform resource allocation to more effectively and efficiently target diabetes programs in India to those most in need.

Introduction

As with other low and middle income countries (LMICs), India is in the midst of a rapid epidemiological transition: the estimated proportion of disability-adjusted life years (DALYs) attributable to non-communicable diseases (NCDs) in India has risen from 31% of total DALYs in 1990 to 53% in 2015.[28] An increasing prevalence of diabetes – a NCD in itself and a major risk factor for other NCDs as well as cardiovascular mortality[29] – is both an important driver and consequence of this transition. The NCD Risk Factor Collaboration estimates suggest that between 1980 and 2014, the age-standardized diabetes prevalence among adults in India has grown from 3.7% to 9.1% in men and 4.6% to 8.3% in women.[30]

In 2015 India had 1.3 billion people,[31] accounting for more than one sixth of the world's population.[31] In addition, India is projected to be the greatest contributor to global population growth until at least 2050.[31] Given that its huge and growing population is also rapidly aging and

urbanizing,[31,32] the country's performance in stemming its diabetes epidemic is crucial to achieving the Sustainable Development Goal 3 (SDG) target of reducing premature mortality from NCDs by one third by 2030 globally.[33] Further, as out-of-pocket spending for diabetes and cardiovascular disease is a major cause of impoverishing healthcare expenditures in LMIC,[12,34] the course of India's diabetes epidemic will also impact on its ability to reduce poverty and achieve universal health coverage.[33]

Despite being an increasingly important public health problem, there has not been a nationally representative analysis of diabetes prevalence in India. Instead, to date prevalence estimates for India have relied on sub-national studies. The largest of these studies (the INDIAB study) measured capillary blood glucose in 57,000 adults across 14 states and one Union Territory,[19] which jointly account for 47% of India's population.[35] This study differentiates itself from the INDIAB study by including participants from all states of India (except Gujarat, and Jammu and Kashmir) and achieving a sample that is representative at the level of the district (rather than the state). There have only been six other studies that were carried out across more than one state, two of which were conducted before 2003 (one only sampled urban populations),[36,37] two were restricted to rural areas,[38,39] and two were limited to select cities.[40,41] All other studies sampled participants in specific locales or communities within a single state,[42-53] or relied on self-report to define diabetes.[54] Even less is known about how diabetes prevalence varies across states, geography, and individual-level socio-demographic characteristics. Yet, it is precisely this information that is needed most urgently for health system planning and targeting of prevention, screening, and treatment programs, and to address social inequities.

As far as we are aware, this is the first nationally representative analysis of biomarker-defined diabetes across India. Our aim was to provide a new diabetes prevalence estimate for India, and to determine how diabetes prevalence in the country varies by state, rural versus urban location, and individual-level socio-demographic characteristics.

Methods

Data sources

This study combines data from the most recent rounds of two large-scale population-based surveys in India: (i) the second update of the Annual Health Survey (AHS) and (ii) the fourth round of the District-Level Household Survey (DLHS-4). The states and Union Territories covered by each survey are shown in **eFigure1**. Jointly, these surveys cover 620 districts across all 29 states of India, except Jammu and Kashmir (where data were not collected due to violent conflicts) and Gujarat (for which data are not available in the public domain). In addition, the DLHS-4 covered five (Andaman and Nicobar Islands, Chandigarh, Daman and Diu, Delhi, and Puducherry) of the seven Union Territories of India. States and Union Territories for which data were unavailable constituted 6% of India's population according to the most recent population census (2011).[35]

The AHS was carried out between 2012 and 2013 and covered 284 districts in the nine states of India with the highest rates of infant and child mortality in the country in 2010: Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Uttar Pradesh, and Uttarakhand.[55] These states accounted for 48% of the country's population in 2011.[35] The AHS used self-weighting two-stage cluster random sampling in each district, stratified by rural or urban

location. In the first stage, 12 primary sampling units (PSU; villages in rural areas and census enumeration blocks in urban areas) per district were selected through simple random sampling with probability proportional to population size (using projections from the 2001 India Census). In the second stage, households were selected through systematic random sampling whereby all non-pregnant household members aged 18 years and older were eligible for blood glucose and body mass index (BMI) assessment. Height, weight, and fasting blood glucose measurements were taken 12-18 months after interviewer administration of a questionnaire that asked participants detailed socio-demographic information and whether they were receiving regular diabetes treatment. Response rates for the AHS have not been published. We matched AHS biomarker data to AHS respondents' socio-demographic data as detailed in **eMethods2** before merging AHS with DLHS-4 data.

The DLHS-4 was conducted between 2012 and 2014 and covered 336 districts in 18 states and five Union Territories (henceforth referred to as 'states') of India that jointly accounted for 46% of India's population in 2011.[35,55] The DLHS-4 used two-stage cluster random sampling for each district stratified by rural versus urban location. In the first stage, rural PSUs (villages) were selected with probability proportional to population size (using projections from the 2001 India Census) and urban PSUs (an 'urban frame survey block') through simple random sampling. In the second stage, households were selected through systematic random sampling whereby all non-pregnant household members aged 18 years and older were eligible for a blood glucose and BMI measurement. The household response rate varied from 87.1% in Meghalaya to 96.5% in Punjab,[56] with the mean response rate across all DLHS-4 households being 92.9%. The response rate for ever-married women within the interviewed households varied from 83.3% in Kerala to

98.4% in Mizoram with the mean being 92.7%. Response rates for men and unmarried women have not been published.

Ascertainment of diabetes

Both AHS and DLHS-4 measured blood glucose in men and non-pregnant women aged 18 years and older. A capillary blood sample (using a finger prick) was taken and blood glucose measured using the SD CodeFree handheld glucometer, which multiplies capillary blood glucose readings by 1.11 to display their plasma equivalent.[57]

Diabetes was defined as having a high plasma reading (≥126 mg/dl if reporting to be fasted or ≥200 mg/dl if reporting to be non-fasted). All participants were asked to fast overnight until the time of the glucose measurement in the morning. Fasting status was verified by self-report in the DLHS-4 but not recorded in the AHS. 58.4% of participants in the DLHS-4 reported to have fasted. The prevalence and regression results in this paper assume all AHS respondents to be fasted. However, we also show prevalence estimates for the nine AHS states assuming all participants were non-fasted.

Because the states covered by the AHS are poorer than those covered by the DLHS-4, the relative differences in diabetes prevalence by household wealth quintile are affected by the choice of plasma glucose cut-off (fasted versus non-fasted) used to define diabetes in the AHS. We therefore conducted a sensitivity analysis re-running all regressions that included household wealth quintile among only those respondents in whom fasting status was verified by self-report (i.e., DLHS-4 participants only).

Ascertainment of socio-demographic characteristics

Independent variables for this study were age, sex, marital status, household wealth quintile, education, and rural or urban location. We created a household wealth index using five key housing characteristics (water supply, type of toilet and whether it is shared, cooking fuel, housing material, and source of lighting) and ownership of 12 assets (radio, TV, computer, phone, fridge, bike, scooter, car, washing machine, sewing machine, house, and land). These variables were combined into a single measure, separately for urban and rural areas, using the first component in a principal component analysis (as per the methodology developed by Filmer and Pritchett[58,59]). This index was then categorised into quintiles (separately for rural and urban areas) based on the distribution in the aggregate dataset. More detail on the computation of the household wealth index is provided in **eMethods3**.

Statistical analysis

We calculated the prevalence of diabetes by state, rural versus urban residence, sex, age group, and household wealth quintile. These prevalence estimates were weighted to account for both the complex survey design and the pooling of AHS with DLHS-4 data. More detail on the computation of the sampling weights is provided in **eMethods4**. National diabetes prevalence was also standardized to the age distribution of the WHO's standard population.[60] In addition, we fit multivariable linear probability models (LPMs) - run separately for rural and urban areas - to further investigate the association of diabetes and hypertension with individual-level socio-demographic characteristics. Our regressions included a binary indicator ('fixed effect') for each of 18,126 primary sampling units (PSUs) to filter out area-level effects on diabetes and hypertension. As there are relatively few observations in each PSU, we fit LPMs rather than

logistic or probit models to avoid the incidental parameter problem.[61] An added advantage of the LPM is the interpretability of the regression coefficients as simple absolute differences in the probability of the outcome. To avoid the possibility of fitted probabilities above one and below zero, we use logistic regression (with district-level fixed effects to sidestep the incidental parameter problem) for predicted probability plots. In addition, we fit a multilevel linear probability model (random intercepts at the level of the district and random slopes for household wealth quintile) with district-level mean household wealth quintile (as an indicator of a district's standard of living) as level 2 variable to investigate the (possible) interaction between an area's standard of living and (individual-level) household wealth. The standard errors in all regression models were adjusted for clustering at the PSU level. Statistical analyses were run in R version 3.3.2 (2016, Vienna, Austria),[62] and all figures were created with the ggplot2 package.[63]

This study received a determination of "Not Human Subjects Research" by the institutional review board of the Harvard T.H. Chan School of Public Health on 23 November 2016 (protocol number: IRB16-1915).

Results

Sample characteristics:

1,618,359 non-pregnant adults were interviewed. 297,804 (18.4%) had a missing value for the plasma glucose measurement, yielding a sample size for analysis of 1,320,555 adults. **Table 1.1** shows the (unweighted) characteristics of the participants. 7.6% of participants had diabetes. 46.9% were male and 43.0% were aged 18 to 35 years. More than a third (38.5%) reported not to have completed primary school. 14.6% of participants were overweight (25 $kg/m^2 \leq$ BMI <30

kg/m^2) and 4.3% obese (BMI ≥30.0 kg/m^2). Less than a third (32.6%) were residing in an urban area. The percentage of observations missing was less than one percent for all variables except wealth quintile (4.4% missing) and BMI (1.8% missing). **eTable1** disaggregates the sample characteristics by whether the blood glucose measurement was missing or not.

Table 1.1. *Sample characteristics*

Characteristic	Total	By sex		By diabetes status	
		Females	*Males*	*With diabetes*	*Without diabetes*
n	1,320,555	701,408	619,147	100,242	1,220,313
Diabetes (%)	100,242 (7.6)	52,019 (7.4)	48,223 (7.8)	100.0	0.0
Male (%)	46.9	0.0	100.0	48.5	46.8
Missing (%)	*0.0*	*NA*	*NA*	*0.0*	*0.0*
Age group (%)					
18-25 years	19.0	18.6	19.5	5.7	20.2
26-35 years	24.0	25.2	22.6	12.6	25.1
36-45 years	21.3	21.8	20.7	20.0	21.4
46-55 years	16.2	16.4	16.0	24.1	15.5
56-65 years	11.6	11.0	12.3	21.8	10.7
>65 years	7.9	7.0	8.9	15.8	7.2
Missing (%)	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Currently married (%)	75.0	75.9	73.9	80.4	74.5
Missing (%)	*0.2*	*0.1*	*0.2*	*0.1*	*0.2*
Wealth quintile (%)					
1 (poorest)	20.1	20.2	20.1	12.1	20.9
2	19.6	19.5	19.8	16.0	20.0
3	19.5	19.5	19.5	20.0	19.5
4	20.1	20.1	20.1	23.8	19.8
5 (richest)	20.6	20.8	20.4	28.2	19.9
Missing (%)	*4.4*	*4.3*	*4.5*	*2.2*	*4.6*
Educational attainment (%)					
<Primary School	38.5	47.2	28.7	38.2	38.5
Primary School	12.4	11.9	13.1	12.7	12.4
Middle School	15.4	13.8	17.3	14.4	15.5
Secondary School	13.9	11.6	16.4	15.7	13.7
High School	9.7	8.0	11.7	7.8	9.9
>High School	10.0	7.6	12.8	11.2	9.9
Missing (%)	*0.4*	*0.4*	*0.5*	*0.2*	*0.4*
BMI (%)					
<18.5 kg/m^2	19.0	20.2	17.7	11.7	19.7
18.5-22.9 kg/m^2	47.3	45.8	49.0	34.6	48.4
23.0-24.9 kg/m^2	14.8	13.9	15.9	17.3	14.6
25.0-29.9 kg/m^2	14.6	15.0	14.1	25.7	13.5
≥30.0 kg/m^2	4.3	5.2	3.3	10.7	3.7
Missing (%)	*1.8*	*1.8*	*1.8*	*1.7*	*1.8*
Urban area (%)	32.6	32.7	32.5	45.9	31.4
Missing (%)	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*

Abbreviations: %=Percentage; BMI=Body Mass Index; kg=kilogram; m=meter

National prevalence of diabetes:

The crude weighted prevalence of diabetes among adults (≥18 years) in India was 7.3% (7.1 - 7.4) among women and 7.8% (7.6 - 8.0) among men (**eTable2**), ranging from 2.4% (95% CI, 2.2 - 2.5) among men aged 18-25 years to 14.0% (95% CI, 13.5 - 14.5) among men above 65 years. The age-standardized prevalence was 6.1% (6.0 - 6.3) and 6.5% (6.4 - 6.7) among women and men, respectively. If all AHS respondents are assumed to be unfasted, the crude prevalence was 5.9% (5.7 - 6.1) among women and 6.1% (5.9 - 6.2) among men (**eTable3**).

Prevalence of diabetes by individual-level socio-demographic characteristics:

Urban areas had higher crude diabetes prevalence than rural areas (**Figure 1.1**). Diabetes prevalence rose with increasing household wealth quintile in all age groups and both sexes in rural areas, and among older age groups (>45 years) in urban areas. In urban areas, the greatest absolute increase in diabetes prevalence occurred between the fourth and the fifth wealth quintile, while in rural areas the increase in diabetes with rising wealth quintile tended to be more gradual. Females and males generally had similar diabetes prevalence across age groups and wealth quintiles.

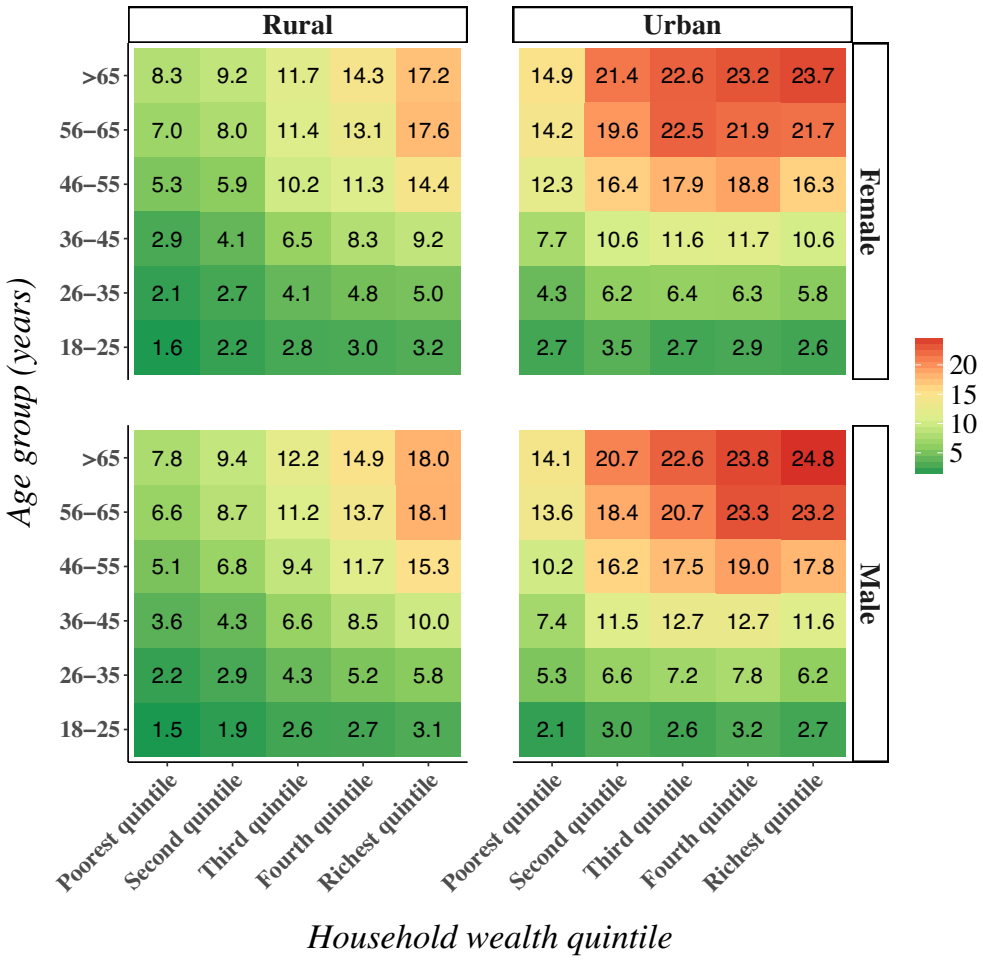


Figure 1.1. Crude prevalence of diabetes by rural versus urban residence, sex, age group, and household wealth quintile.

Regressing diabetes separately for rural and urban areas onto individuals' socio-demographic characteristics and PSU-level fixed effects shows that age group is the strongest correlate of diabetes (**Table 1.2**). Those in the highest household wealth quintile only had a moderately higher probability of diabetes than those in the poorest quintile (rural areas: 2.81 percentage points [2.53 - 3.08]; urban areas: 3.47 percentage points [3.03 - 3.91]). The absolute differences in the probability of diabetes between education groups were generally small (all less than one percentage point). Males had a statistically significantly higher probability of diabetes but the

difference between the sexes was only 0.31 percentage points (0.21 - 0.42) in rural areas and 0.56 (0.37 - 0.74) percentage points in urban areas. The regression results were qualitatively similar when restricting the sample to participants in whom fasting status was ascertained through self-report (**eTable5**).

Table 1.2. *Multivariable linear regressions of diabetes on socio-demographic characteristics and PSU-level fixed effects*[a,b,c]

Characteristic	Rural		Urban	
	Difference in probability [c] ***(95% CI)***	***P***	***Difference in probability*** [c] ***(95% CI)***	***P***
Age group				
18-25 years	Ref.		Ref.	
26-35 years	1.42 (1.28 - 1.57)	<0.001	2.57 (2.33 - 2.81)	<0.001
36-45 years	3.76 (3.57 - 3.95)	<0.001	7.04 (6.71 - 7.36)	<0.001
46-55 years	6.60 (6.36 - 6.83)	<0.001	12.11 (11.70 - 12.52)	<0.001
56-65 years	8.82 (8.53 - 9.10)	<0.001	15.86 (15.36 - 16.36)	<0.001
>65 years	9.96 (9.63 - 10.29)	<0.001	17.09 (16.51 - 17.67)	<0.001
Wealth quintile				
1 (poorest)	Ref.		Ref.	
2	0.27 (0.11 - 0.44)	<0.001	1.04 (0.72 - 1.36)	<0.001
3	0.59 (0.40 - 0.79)	<0.001	2.10 (1.73 - 2.46)	<0.001
4	1.12 (0.90 - 1.34)	<0.001	2.92 (2.53 - 3.32)	<0.001
5 (richest)	2.81 (2.53 - 3.08)	<0.001	3.47 (3.03 - 3.91)	<0.001
Education				
<Primary School	Ref.		Ref.	
Primary School	0.63 (0.46 - 0.81)	<0.001	0.77 (0.39 - 1.14)	0.522
Middle School	0.51 (0.35 - 0.68)	<0.001	0.66 (0.31 - 1.00)	0.864
Secondary School	0.57 (0.37 - 0.77)	<0.001	0.57 (0.22 - 0.91)	0.001
High School[d]	-0.24 (-0.46 - -0.01)	0.039	-0.16 (-0.53 - 0.20)	0.383
>High School[d]	-0.40 (-0.68 - -0.12)	0.005	-0.90 (-1.28 - -0.52)	<0.001
Currently married	-0.02 (-0.16 - 0.13)	0.831	0.21 (-0.04 - 0.46)	0.094
Male	0.31 (0.21 - 0.42)	<0.001	0.56 (0.37 - 0.74)	<0.001

Abbreviations: PSU=Primary Sampling Unit; CI=Confidence Interval; Ref.=Reference category.

[a] These linear probability models included all socio-demographic variables listed in the table (age group, wealth quintile, education, marital status, and sex) and a binary indicator for each PSU (PSU-level fixed effects). Standard errors were adjusted for clustering at the PSU level.

[b] These regressions assumed all AHS participants to be fasted at the time of the blood glucose measurement. Regression results assuming that all AHS participants were unfasted are shown in **eTable4**. **eTable5** shows the regression results when restricting the sample to those in whom fasting status was verified through self-report (i.e., DLHS-4 participants only).

[c] The regression coefficients (denoted as "Difference in probability") should be interpreted as the average absolute difference (in percentage points) in the probability of having diabetes compared to the reference category.

Figure 1.2 demonstrates that (i) the absolute differences in the probability of diabetes between wealth quintiles were higher in older than younger age groups, (ii) among all wealth quintiles, the probability of diabetes increased more steeply with age in urban than in rural areas, and (iii) the largest absolute difference in the probability of diabetes between subsequent wealth quintiles in urban areas was between the first (the poorest) and the second quintile.

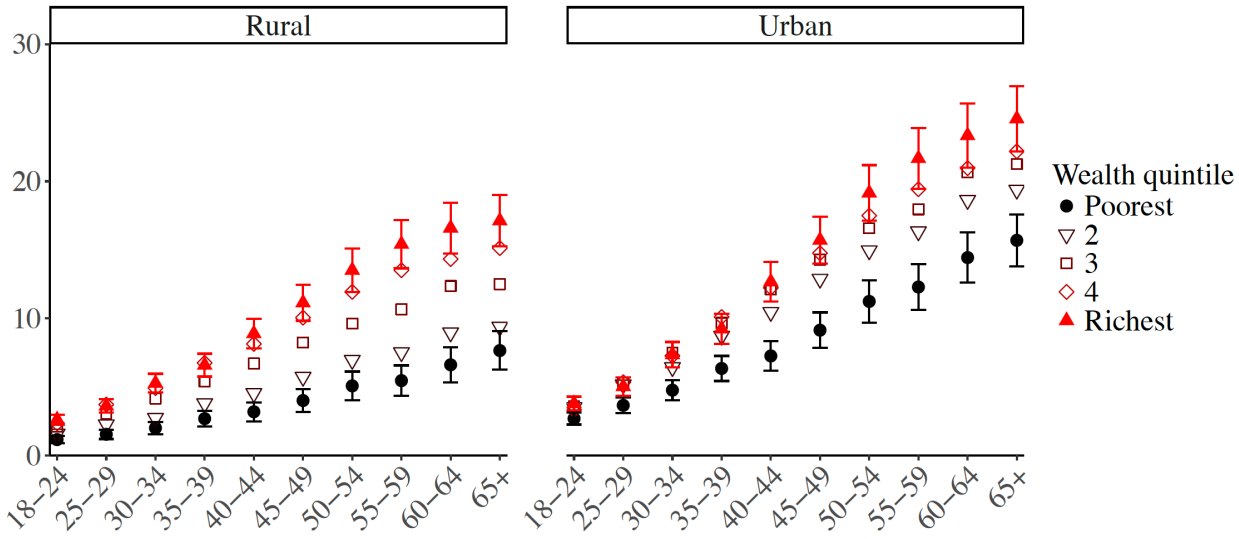


Figure 1.2. The predicted probability of diabetes and hypertension by age group, rural-urban location, and household wealth quintile[a,b]

[a] Predicted probabilities were obtained from multivariable logistic regressions of diabetes and hypertension on individuals' socio-demographic characteristics (age group, household wealth quintile, education, marital status, sex, and rural-urban location), district-level fixed effects, and an interaction term between age group and household wealth quintile.

[b] Predicted probabilities assuming that all AHS respondents were unfasted are shown in eFigure6.

Prevalence of diabetes by state:

The age-standardized prevalence of diabetes varied from 2.33% (95% CI, 1.98 - 2.75) among females in Madhya Pradesh to 17.90% (95% CI, 15.37 - 20.74) among males in Goa (**Figure 1.3** and **eTable6**). In general, there was a higher diabetes prevalence in South India than in other regions. **eTable6, eTable7**, and **eTable8** show state-level prevalence estimates and CIs by sex, rural versus urban residence, and age group. We also detail these estimates when we assumed AHS participants were non-fasted rather than fasted (**eTable9, eTable10, and eTable11**). State- and district-level prevalence was positively associated with the standard of living in a state/district as measured by the mean household wealth quintile in a state/district (**eFigure8**). Interacting district-level mean household wealth quintile with (individual-level) household wealth quintile in a multilevel model shows that this positive association between a district's standard of living and diabetes did not exist in the richest household wealth quintile (**eFigure9**).

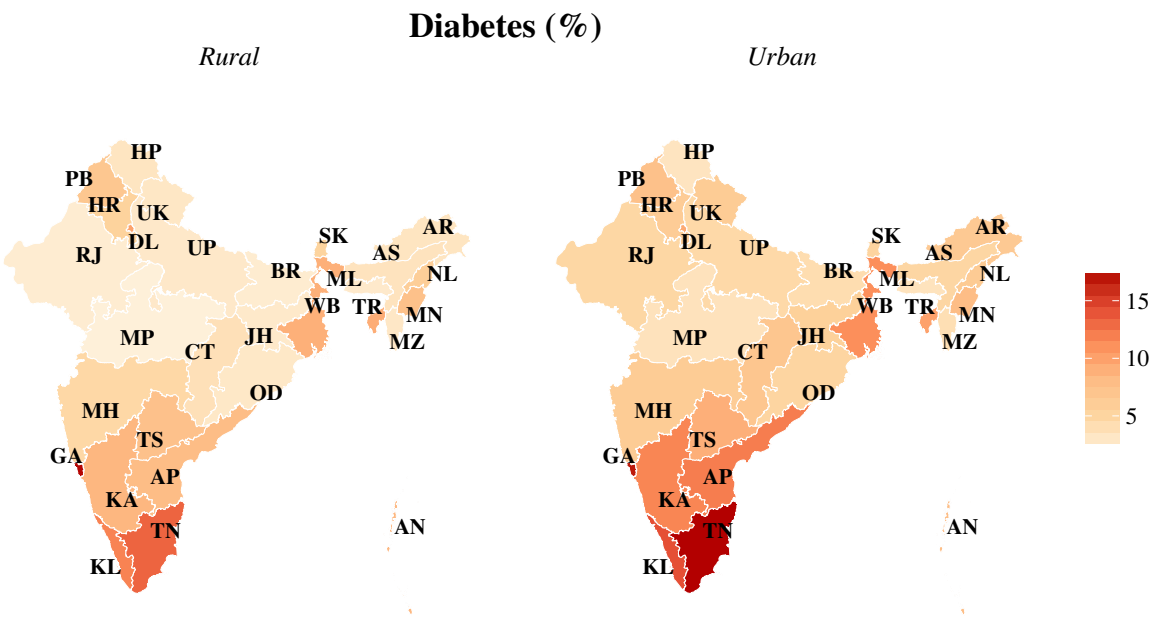


Figure 1.3. Age-standardized prevalence of diabetes by state[1]

[1] The Union Territories Chandigarh, Daman and Diu, and Puducherry are not visible in the map due to their small area.

Discussion

Our study is the first to analyze nationally representative, individual-level biomarker-based data on diabetes in India, which has over a sixth of the world's population and 22% of the population in LMICs.[31] Our analysis found that diabetes is common in middle and older age across all geographic settings and population groups in the country. While household wealth and living in an urban area were positively associated with diabetes, the prevalence of diabetes in middle and

old age among the lowest wealth quintile in rural areas was still high. For instance, among those older than 40 years in the poorest wealth quintile in rural areas, 5.9% (95% CI, 5.5 - 6.2) had diabetes. Diabetes was also common across education groups in the country. These findings are unlikely to be a result of applying a fasting blood glucose threshold to non-fasted AHS participants. In fact, the prevalence of diabetes in the lowest *national* wealth quintile in DLHS-4 participants (for whom fasting status was verified through self-report) was considerably higher than among AHS respondents.

With this cross-sectional survey data, we could not ascertain to what degree the impact of diabetes on mortality, morbidity, and impoverishing healthcare expenditures differs between wealth and education groups. However, studies in India and other LMIC strongly suggest that the poor are more likely to be undiagnosed and untreated,[64-67] and more likely to experience impoverishing healthcare expenditures from NCD care than the wealthy.[12,66,68] This consideration, along with the high diabetes prevalence observed throughout wealth quintiles (particularly in older age groups, urban areas, and districts with a high diabetes prevalence and/or mean household wealth) and education groups in this study, implies that health system efforts to stem the diabetes epidemic in India should not be limited to wealthier or more educated strata of society. Instead, investments into far-reaching and comprehensive diabetes prevention, screening, and treatment programs are needed. The return of these investments on health, economic growth,[16,69,70] and financial risk protection will substantially influence the country's performance in achieving the SDG targets of ending poverty, reducing premature mortality from NCDs by one third, and attaining universal health coverage.[33]

Currently, however, India's investment in the health system, and the prevention and care of NCDs is insufficient. The country has one of the lowest total health expenditures as a proportion of gross domestic product (GDP) in the world (3.9% in 2013),[13] and the highest proportion of total health expenditures from out-of-pocket payments of any 'BRICS' (Brazil, Russia, India, China, and South Africa) country (with governmental health spending at only 1.4% of GDP).[13] Further, despite the rapid epidemiological transition, which has brought a large burden of NCDs, India's national health policy – like that of most other LMIC[71] – has a continued focus on communicable diseases.[72]

Our finding of a relatively high diabetes prevalence among the poor and less educated, along with the observation that the relative differences in diabetes prevalence between wealth quintiles might be decreasing, lends support to those who have argued that NCDs are not merely a problem of aging, affluence, and lifestyle choices.[73-75] With diabetes being a major risk factor for other NCDs, our results suggest that the type of NCDs suffered by the world's poorest billion – 58% of whom are estimated to be living in India[76] - may overlap to a large degree with those affecting wealthier groups. While more research is needed, this provides some evidence against the hypothesis put forward by some groups, including the Lancet Commission for Reframing NCDs and Injuries for the Poorest Billion,[73] that the world's poorest suffer mostly from different types of NCDs than wealthier groups.

We were only able to study the prevalence of one disease (diabetes) among different socio-demographic groups rather than the proportion of each group's total disease burden that is caused by diabetes. Specifically, India still faces a large burden of infectious diseases and has poor

maternal and child health indicators in many states.[77] Because these diseases disproportionately affect the poor, it is plausible that despite a relatively high prevalence, diabetes only accounts for a small proportion of the total disease burden among the poor and less educated. Hence, in order to inform Indian policy makers on the degree to which diabetes prevention and care should be prioritized to improve the health and economic well-being of the indigent, more research is needed on the relative disease burden caused by diabetes and related NCDs compared to other diseases among the poor. Ideally, such research should also take into account the interaction between non-communicable and communicable diseases, including the higher risk of active tuberculosis in individuals with diabetes.[78]

Our study has several limitations, which we tried to address where possible. First, a one-time capillary blood glucose measurement is not recommended for the diagnosis of diabetes in clinical settings.[79] It has, however, been shown to have an acceptable sensitivity and specificity for defining diabetes in population-based research, and is the recommended method for monitoring diabetes prevalence in the WHO's STEPwise Approach to Non-communicable Disease Risk-Factor Surveillance.[80-82] Second, the study was unable to distinguish between type 1 and type 2 diabetes. However, the International Diabetes Federation estimates that 72,000 children with type 1 diabetes aged zero to 14 years lived in India in 2015, which was merely 0.02% of the country's population in this age range.[31,83] Extrapolating this percentage to adults would suggest that the proportion of adults with type 1 diabetes in our sample is likely very small. Third, a substantial proportion (18.4%) of blood glucose measurements were missing. Fourth, fasting status was not ascertained in the AHS. We addressed this limitation by additionally providing prevalence estimates assuming that all AHS respondents were non-fasted

instead of fasted, and by showing regression results after restricting the sample to DLHS-4 respondents. Last, and maybe most importantly, only participants with a high blood glucose measurement were considered to have diabetes because no information on diabetes treatment was available in the data. Thus, participants on diabetes medications who achieved a normal blood glucose will not have been counted as diabetic in this analysis – our prevalence estimate is therefore likely an underestimate. In addition, given that wealthier individuals are more likely to be on treatment for diabetes, the wealth gradients observed in this analysis are likely more shallow than they would have been had full information on treatment been available.

While the key strength of this study is its ability to disaggregate prevalence by state and individual-level socio-demographic characteristics, we also provide a new diabetes prevalence estimate for India that does not extrapolate from sub-national studies. **eFigure12** shows our age-standardized prevalence estimate and confidence interval in comparison to that of existing national prevalence estimates for adults in India. We observed an age-standardized diabetes prevalence of 6.3% (6.2-6.5). This figure is lower than the age-standardized estimates provided by the International Diabetes Federation (which has estimated an adult prevalence of 9.3% [7.6 to 11.4] for 2015),[83] the NCD Risk Factor Collaboration (estimating an adult prevalence of 9.1% [5.2 to 14.2] for 2014),[30] and the Global Burden of Disease Project (estimating an age-standardized prevalence among the *entire population* of 6.5% [uncertainty range: 6.0-7.1] in 2015).[84] While our prevalence figures are lower than these modelled estimates, our state-level prevalence estimates are very similar to those obtained in the largest sub-national study to date, mentioned in the introduction. Regardless, the prevalence of diabetes in the country will likely continue to rise rapidly with urbanising and aging of the Indian population; the urban population

is projected to increase from 30.9% in 2010 to 50.3% in 2050 (adding the largest absolute number of urban dwellers globally of any country),[32] and the share of the country's population aged 60 years and older is estimated to rise from 8.9% in 2015 to 19.4% in 2050.[31]

In conclusion, while we found a lower national prevalence of diabetes than has been estimated thus far, India's diabetes epidemic is evident across different wealth and education groups in middle and old age, and the differences in diabetes prevalence between wealth groups may be narrowing in younger generations and as standards of living in India are rising. The implication of our finding is that a major investment in diabetes prevention, detection, and treatment programs aimed at improving health access, consistent care, and financial risk protection is likely needed across the country if India is to avert catastrophic health, social, and economic consequences of diabetes. Given the size, growth, rapid urbanization, and aging of India's population,[31,32] as well as the high levels of impoverishing healthcare expenditures caused by NCDs,[12] the country's success in tackling its diabetes epidemic will be crucial to achieving the SDGs not just in India, but globally.

PAPER 2

Hypertension in India: A nationally representative study of 1.3 million adults

Abstract

Importance: Understanding how the prevalence of hypertension varies within a country as large as India is essential for the targeting and planning of relevant healthcare services. However, there has been no previous nationally representative study of hypertension in India to guide policy makers.

Objective: To determine the prevalence of hypertension in India and its variation between states, rural versus urban location, and by individual-level socio-demographic characteristics.

Design: Cross-sectional nationally representative study carried out between 2012 and 2014.

Setting: Population-based.

Participants: 1,320,555 adults with a blood pressure (BP) measurement.

Exposures: State, district, rural versus urban location, age, sex, household wealth, educational attainment, and marital status.

Main measure: Hypertension (systolic BP ≥140mmHg or diastolic BP ≥90mmHg).

Results: The crude prevalence of hypertension was 23.6% (95% CI: 23.4 – 23.7) among females and 27.3% (95% CI: 27.1 – 27.5) among males. Prevalence ranged from 12.1% (95% CI: 11.8 - 12.5) in those aged 18-25 years to 45.6% (95% CI: 45.0 - 46.2) in those aged 65 years and older. Prevalence was highest in the Northern states of Punjab and Himachal Pradesh, the Northeastern states of Sikkim and Nagaland, and the Southern state of Kerala. Hypertension was not

associated with education and weakly associated with household wealth quintile (OR for the richest versus the poorest quintile: 1.13 [95% CI: 1.10 – 1.16] in rural and 1.10 [95% CI: 1.06-1.14] in urban areas).

Conclusions and relevance: We found the national prevalence of hypertension to be lower than previously estimated by the WHO. Importantly, however, we identified a substantially higher prevalence among young adults than the WHO estimated for South Asia and any other region in the world, which will – if untreated – likely translate to a rise in CVD in India in the future. The substantial variation in hypertension prevalence between states, rural versus urban areas, sex, and age groups identified by this study should guide the targeting of hypertension screening and treatment efforts across the country. In addition, given that we found a high prevalence in nearly all population subgroups, there is an urgent need in India for public health approaches to reduce blood pressure at the population level.

Introduction

Hypertension is the leading risk factor for mortality from CVD and chronic kidney disease in all regions of the world.[85] Given that CVD is the top cause of death globally,[1] the health consequences of hypertension are therefore immense. In 2011, WHO member states signed the Global Action Plan for the Prevention and Control of Non-Communicable Diseases (the '25x25 initiative'),[20] which aims to reduce the prevalence of hypertension by 25% between 2010 and 2025. In addition, the target of SDG 3.4 is to reduce by one third premature mortality from non-communicable diseases by 2030. India will play a crucial role in achieving these targets, given that the country is thought to have contributed 19% of the global CVD burden (as measured by disability-adjusted life years) in 2015.[2] Importantly, this proportion is likely to increase in the

future given that i) India will add the highest number of people to global population growth of any country until at least 2050,[31] ii) India's population is aging and urbanizing rapidly,[31,32] and iii) the country is experiencing rapid economic growth,[11] which is frequently accompanied by an increase in obesity and its associated cardiovascular risk factors, including hypertension.[86] The latter is particularly worrying given that adults of Asian Indian ethnicity are thought to be predisposed to developing CVD when exposed to obesogenic environments and lifestyles.[87]

Although the cardiovascular consequences of hypertension – such as myocardial infarction, angina, and stroke - are costly to treat, the management of hypertension is relatively less costly and less complex, providing the opportunity to effectively and efficiently address this condition and mitigate adverse outcomes in low-resource settings. Diagnosing hypertension does not require laboratory services nor a high level of training.[88] Similarly, many effective hypertensive medications are generic and should be available at low cost.[17] However, it has been estimated that less than half of hypertensive adults in LMICs have been diagnosed and only around a third are on treatment.[89] While evidence is sparse, the situation appears to be similar, or even worse, in India.[18] In order to inform planning, and more efficient and effective targeting of resources in India's health system, it is essential to understand how the prevalence of hypertension varies among population groups across the country. Yet, to date, there has not been a nationally representative study of hypertension in India to guide policy makers.[18] Pooling data from a nationally representative sample of 1.4 million adults, this study aims to determine how the prevalence of hypertension in India varies between states, rural versus urban location, and by individual-level socio-demographic characteristics.

Methods

Data sources:

We pooled data from two large household surveys in India: The District-Level Household Survey-4 (DLHS-4) and the second update of the Annual Health Survey (AHS). **eFigure1** shows the states and Union Territories covered by each survey. Both surveys are representative at the district-level. They jointly cover all 29 states of India except Jammu and Kashmir (data were not collected due to violent conflicts) and Gujarat (data were not available in the public domain), and five of India's seven Union Territories (data were not available for Dadra and Nagar Haveli, and Lakshadweep). The two states and two Union Territories not included in this analysis only accounted for 6% of India's population in 2011 (the time of the last census).[35] Both surveys administered a questionnaire to the household head to ascertain socio-demographic information for each household member (regardless of whether the individual was present or absent at the time of the interviewer's visit), and measured blood pressure (BP) twice in each household member aged 18 years and older using an electronic BP monitor (Rossmax AW150).

Annual Health Survey:

Data for the AHS were collected between 2012 and 2013 in all 284 districts of nine states of India, which were selected because they had the highest rate of infant and child mortality in the country in 2010.[55] The two-stage cluster random sampling design of the AHS was self-weighting at the district level. In the first stage, villages in rural areas and census enumeration blocks in urban areas were selected through simple random sampling with probability proportional to population size (using projections from the 2001 India Census). In the second stage, households were selected through systematic random sampling (sampling the first household randomly, and

then selecting every alternate household). The AHS dataset containing participants' socio-demographic information was merged with the dataset containing BP measurements as outlined in **eMethods2.**

District-Level Household Survey-4:

Data for the DLHS-4 were collected between 2012 and 2014 in all 336 districts of 18 states and five Union Territories (henceforth also referred to as 'states') of India.[55] In the first stage, census villages in rural areas were selected through probability proportional to population size (again, using projections from the 2001 India Census), and urban frame survey blocks in urban areas through simple random sampling. In the second stage, households were selected through systematic random sampling.[90]

Definition of outcome and explanatory variables:

A binary indicator for hypertension was the outcome variable in this analysis. Using the average of the two BP measurements, we defined hypertension as mean systolic BP ≥140 mmHg or mean diastolic BP ≥90 mmHg.[91] The explanatory variables for this study were state, household wealth quintile, education, marital status, and whether the household was located in a rural or urban area. We used household ownership of 12 assets (radio, TV, computer, phone, fridge, bike, scooter, car, washing machine, sewing machine, house, and land) and five key housing characteristics (water supply, type of toilet and whether it is shared, cooking fuel, housing material, and source of lighting) to generate the household wealth index in a principal component analysis (PCA). Following the methodology developed by Filmer and Pritchett,[58,59] we extracted the first component in the PCA separately for urban and rural areas, and divided this variable

into quintiles (again, separately for rural and urban areas) based on the distribution in the national dataset. More detail on the computation of the household wealth quintiles is provided in **eMethods3**.

Statistical analysis:

Hypertension prevalence was calculated by state, rural versus urban residence, sex, age group, and household wealth quintile using sampling weights to account for both the survey design and the pooling of AHS with DLHS-4 data. More detail on the computation of the sampling weights is provided in **eMethods4**. Age-standardized prevalence estimates were weighted to the age distribution of the WHO's standard population.[60] To investigate how district-level hypertension prevalence and the difference in prevalence between urban and rural areas in a district was associated with the population's standard of living, we plotted these outcomes against the district-level mean household wealth quintile. These were the only analyses for which we used a household wealth index that was *not* created separately for rural and urban areas to avoid possible bias from the fact that the degree of urbanization varied between districts.

We fit multivariable linear probability models (LPMs) - run separately for rural and urban areas - to further investigate the association of hypertension with individual-level socio-demographic characteristics. Our regressions included a binary indicator ('fixed effect') for each of 18,126 primary sampling units (PSUs) to filter out area-level effects on hypertension. As there are relatively few observations in each PSU, we fit LPMs rather than logistic or probit models to avoid the incidental parameter problem.[61] An added advantage of the LPM is the interpretability of the regression coefficients as simple absolute differences in the probability of the outcome.

The standard errors in all regression models were adjusted for clustering at the PSU level. Statistical analyses were implemented in R version 3.3.2 (2016, Vienna, Austria),[62] and all figures were created with the ggplot2 package.[63]

This study received a determination of "Not Human Subjects Research" by the institutional review board of the Harvard T.H. Chan School of Public Health on 23 November 2016 (protocol number: IRB16-1915).

Results

Sample characteristics:

1,618,359 non-pregnant adults were interviewed. 297,804 (18.4%) had a missing value for at least one of the two BP readings, yielding a sample size for analysis of 1,320,555 adults. **Table 2.1** shows the (unweighted) characteristics of the participants. 26.5% of participants had hypertension. 43.4% of participants were aged 18 to 35 years. 47.0% of women and 28.6% of men had not completed primary school. Three quarters of participants were married and a third (32.5%) were living in urban areas.

***Table 2.1**. Sample characteristics*[a,b,c]

	Total	Female	Male
n	1,320,555	701,408	619,147
Hypertension, no. (%)	350,273 (26.5)	170,145 (24.3)	180,128 (29.1)
Age group, no. (%)			
18-25 years	253154 (19.2)	131,388 (18.7)	121,766 (19.7)
26-35 years	320,018 (24.2)	178,779 (25.5)	141,239 (22.8)
36-45 years	281,706 (21.3)	153,249 (21.8)	128,457 (20.7)
46-55 years	212,465 (16.1)	114,018 (16.3)	98,447 (15.9)
56-65 years	150,940 (11.4)	75,911 (10.8)	75,029 (12.1)
>65 years	102,253 (7.7)	48,056 (6.9)	54,197 (8.8)
Education, no. (%)			
<Primary School	504,829 (38.4)	328,296 (47.0)	176,533 (28.6)
Primary School	163,953 (12.5)	83,338 (11.9)	80,615 (13.1)
Middle School	203,128 (15.4)	96,659 (13.8)	106,469 (17.3)
Secondary School	182,391 (13.9)	81,380 (11.6)	101,011 (16.4)
High School[d]	128,270 (9.8)	55,876 (8.0)	72,394 (11.7)
>High School[d]	132,544 (10.1)	53,329 (7.6)	79,215 (12.9)
Household wealth quintile, no. (%)			
1 (poorest)	254,652 (20.2)	135,454 (20.2)	119,198 (20.2)
2	248,101 (19.7)	130,896 (19.5)	117,205 (19.8)
3	245,748 (19.5)	130,413 (19.4)	115,335 (19.5)
4	253,905 (20.1)	134,977 (20.1)	118,928 (20.1)
5 (richest)	259,491 (20.6)	139,077 (20.7)	120,414 (20.4)
Currently married, no. (%)	988,456 (75.0)	532,786 (76.0)	455,670 (73.7)
Urban area, no. (%)	429,330 (32.5)	228,954 (32.6)	200,376 (32.4)

Abbreviations: no.=number; %=Percentage.

[a] These figures were not weighted using sampling weights.

[b] These sample characteristics are for all participants who had a non-missing blood glucose and blood pressure measurement. Sample characteristics stratified by whether the blood pressure measurement was missing are shown in **eTable1**.

[c] The percentage missing for all socio-demographic variables (i.e., age, education, household wealth, marital status, and urban-rural location) was less than 0.5% except for household wealth quintile (4.4% of observations were missing).

[d] Generally referred to as 'higher secondary school' in the Indian school system.

National prevalence of hypertension:

The crude prevalence of hypertension was 25.3% (95% confidence interval [CI]: 25.2 – 25.4). While, overall, hypertension prevalence was higher among males (27.3% [27.1 – 27.5]) than

females (23.6% [23.4 – 23.7]), females had a higher prevalence in older age groups (56-65 years and >65 years) than males (**Table 2.2**). Age-standardized to the WHO standard population, hypertension prevalence was 22.1% (22.0 – 22.2); 24.5% (24.3 – 24.6) among males and 20.0% (19.9 – 20.1) among females.

Table 2.2*. Crude hypertension prevalence by age group and sex*

Age group	**Female** *Percent (95% CI)*	**Male** *Percent (95% CI)*
18-25 years	9.5 (9.2 - 9.8)	15.0 (14.5 - 15.4)
26-35 years	14.3 (13.9 - 14.7)	21.0 (20.6 - 21.5)
36-45 years	23.1 (22.6 - 23.5)	27.6 (27.1 - 28.1)
46-55 years	32.6 (32.2 - 33.1)	33.7 (33.1 - 34.3)
56-65 years	41.1 (40.5 - 41.7)	39.0 (38.3 - 39.6)
>65 years	48.3 (47.6 - 49.0)	43.2 (42.5 - 43.9)
Total	*23.6 (23.4 – 23.7)*	*27.3 (27.1 – 27.5)*

Abbreviations: CI=Confidence Interval.

Prevalence of hypertension by individuals' socio-demographic characteristics:

Prevalence of hypertension tended to be higher among older adults, those in urban areas, and wealthier individuals (**Figure 2.1**). In the youngest age group (ages 18-25 years), hypertension prevalence ranged from 8.4% among rural females in the fourth wealth quintile to 19.4% among urban males in the highest wealth quintile. The positive gradient by household wealth quintile

was less strong in urban than in rural areas. **eFigure4** shows that hypertension was less strongly associated with education than with household wealth.

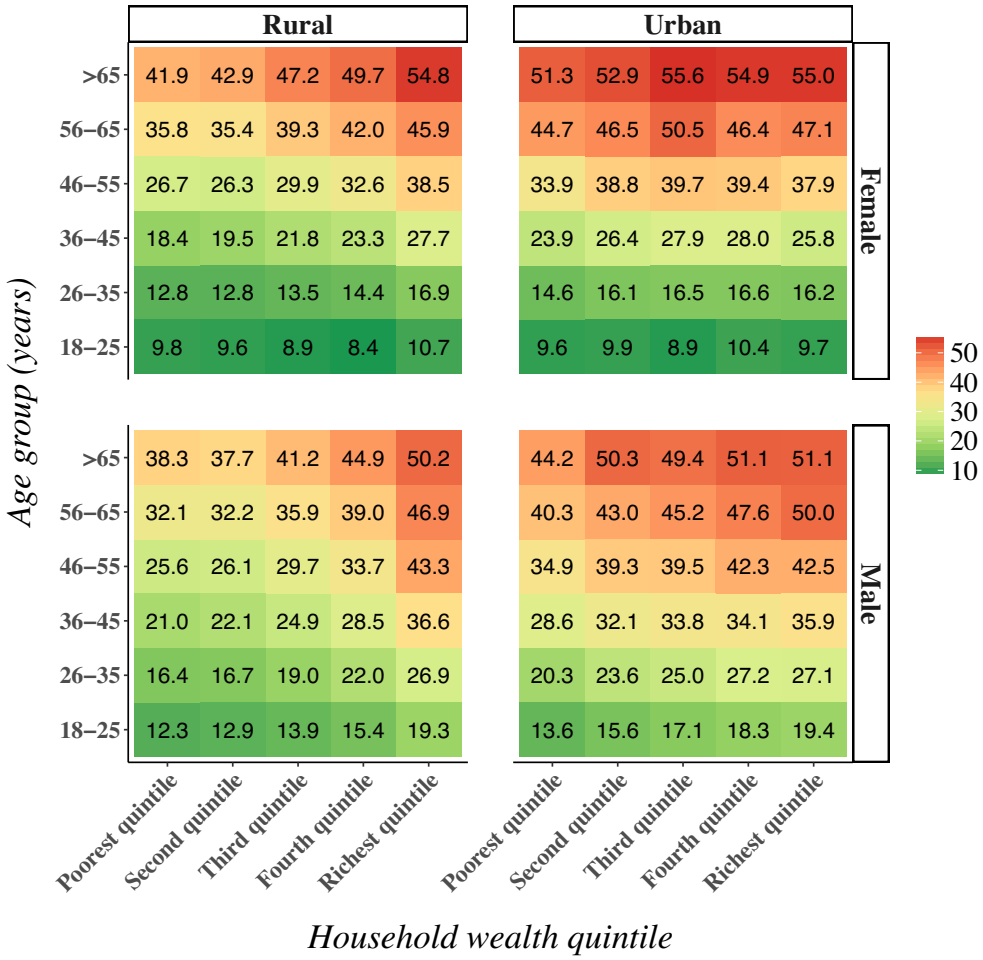


Figure 2.1. Crude prevalence of hypertension by rural versus urban residence, sex, and household wealth quintile

Regressing hypertension on individuals' socio-demographic characteristics (age, household wealth quintile, education, marital status, and sex) and PSU-level fixed effects shows that the absolute differences in the probability of hypertension between household wealth quintiles were relatively small (e.g., rural areas: 4.15 percentage points [3.68 - 4.61] for the richest versus the poorest quintile; urban areas: 3.01 percentage points [2.38 - 3.65] for the richest versus the

poorest quintile) (**Table 2.3**). The absolute differences in the probability of hypertension between education groups were less than two percentage points for all education groups (compared ot those not completing primary school). On average, males had a 3.64 (3.23 - 3.70) percentage points higher probability of hypertension in rural areas and 5.99 (5.67 - 6.31) percentage points in urban areas.

Table 2.3 Multivariable linear regressions of hypertension on socio-demographic characteristics and PSU-level fixed effects[a,b,c]

Characteristic	Rural		Urban	
	Difference in probability*[c] *(95% CI)	***P***	***Difference in probability*[c] *(95% CI)***	***P***
Age group				
18-25 years	Ref.		Ref.	
26-35 years	6.68 (6.39 - 6.96)	<0.001	8.12 (7.71 - 8.52)	<0.001
36-45 years	14.33 (13.98 - 14.68)	<0.001	17.84 (17.34 - 18.34)	<0.001
46-55 years	21.84 (21.41 - 22.27)	<0.001	27.49 (26.89 - 28.08)	<0.001
56-65 years	28.76 (28.26 - 29.26)	<0.001	34.52 (33.84 - 35.19)	<0.001
>65 years	34.77 (34.19 - 35.35)	<0.001	39.78 (39.00 - 40.56)	<0.001
Wealth quintile				
1 (poorest)	Ref.		Ref.	
2	0.14 (-0.18 - 0.46)	0.402	1.35 (0.87 - 1.83)	<0.001
3	0.84 (0.47 - 1.20)	<0.001	2.43 (1.90 - 2.96)	<0.001
4	1.95 (1.55 - 2.35)	<0.001	2.77 (2.21 - 3.34)	<0.001
5 (richest)	4.15 (3.68 - 4.61)	<0.001	3.01 (2.38 - 3.65)	<0.001
Education				
<Primary School	Ref.		Ref.	
Primary School	0.57 (0.27 - 0.88)	<0.001	-0.04 (-0.57 - 0.48)	0.867
Middle School	0.36 (0.06 - 0.67)	0.018	-0.30 (-0.81 - 0.20)	0.239
Secondary School	0.47 (0.13 - 0.80)	0.007	-0.29 (-0.79 - 0.21)	0.259
High School[d]	-0.26 (-0.67 - 0.14)	0.200	-1.61 (-2.16 - -1.06)	<0.001
>High School[d]	0.15 (-0.35 - 0.64)	0.562	-1.72 (-2.28 - -1.17)	<0.001
Currently married	-2.62 (-2.88 - -2.35)	<0.001	-2.14 (-2.51 - -1.78)	<0.001
Male	3.46 (3.23 - 3.70)	<0.001	5.99 (5.67 - 6.31)	<0.001

Abbreviations: PSU=Primary Sampling Unit; CI=Confidence Interval; Ref.=Reference category.

[a] These linear probability models included all socio-demographic variables listed in the table (age group, wealth quintile, education, marital status, and sex) and a binary indicator for each PSU (PSU-level fixed effects). Standard errors were adjusted for clustering at the PSU level.

[b] These regressions assumed all AHS participants to be fasted at the time of the blood glucose measurement. Regression results assuming that all AHS participants were unfasted are shown in eTable4. eTable5 shows the regression results when restricting the sample to those in whom fasting status was verified through self-report (i.e., DLHS-4 participants only).

[c] The regression coefficients (denoted as "Difference in probability") should be interpreted as the average absolute difference (in percentage points) in the probability of having diabetes/hypertension compared to the reference category.

[d] Generally referred to as 'higher secondary school' in the Indian school system.

State- and district-level prevalence of hypertension:

The age-standardized prevalence of hypertension varied from 13.6% (12.2 – 15.0) among females in Chattisgarh to 43.4% (38.3 – 48.7) among males in Daman and Diu. Excluding Union Territories, hypertension prevalence tended to be highest in the Northern states of Punjab and Himachal Pradesh, the Southern state of Kerala, and the Northeastern states of Sikkim and Nagaland (**Figure 2.2**). The state- and district-level prevalence of hypertension was positively correlated with standard of living (as measured by the state- or district-level mean household wealth quintile) (**eFigure10**). **eFigure11** shows that there was no substantial interaction between household wealth quintile and a district's standard of living (as measured by district-level mean household wealth quintile).

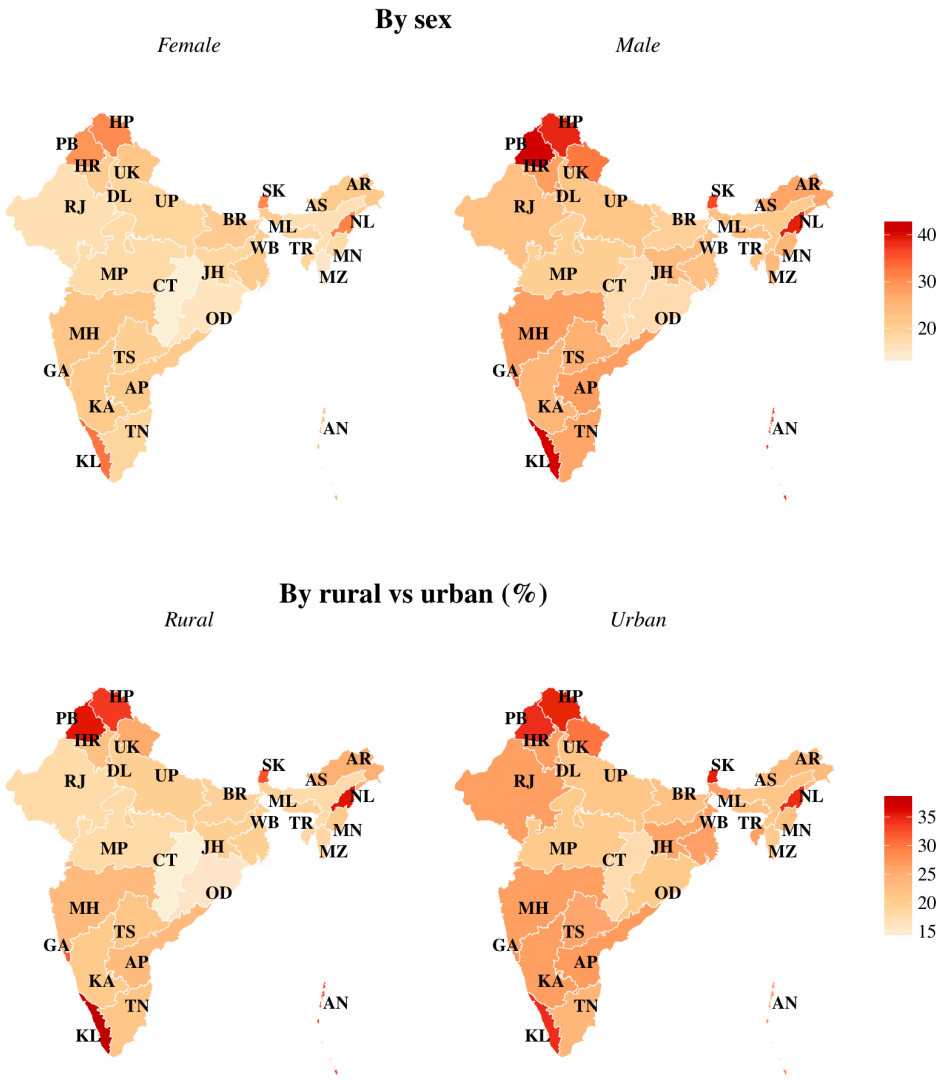


Figure 2.2. Age-standardized state-level prevalence of hypertension by sex and rural versus urban residence within each state[1,2]

[1] The map does not show Jammu and Kashmir, and Gujarat (no data available in the public domain).

[2] The Union Territories, Chandigarh, Daman and Diu, and Puducherry are not visible in the map due to their small area.

[3] Point estimates and 95% confidence intervals for each state are shown in **eTable6**, **eTable7**, and **eTable8.**

Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CT, Chhattisgarh; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram;

NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal

While hypertension prevalence tended to be higher in urban compared to rural areas, the opposite was the case in Andaman and Nicobar, Arunachal Pradesh, Goa, Kerala, Nagaland, and Punjab. Both the absolute and relative difference in hypertension prevalence between urban and rural areas within each district was negatively associated with the standard of living in a district as measured by the district-level mean household wealth quintile (**Figure 2.3**). State-level age-standardized prevalence estimates (with 95% CIs) by sex and rural versus urban location are detailed in **eTable6**, **eTable7**, and **eTable8**.

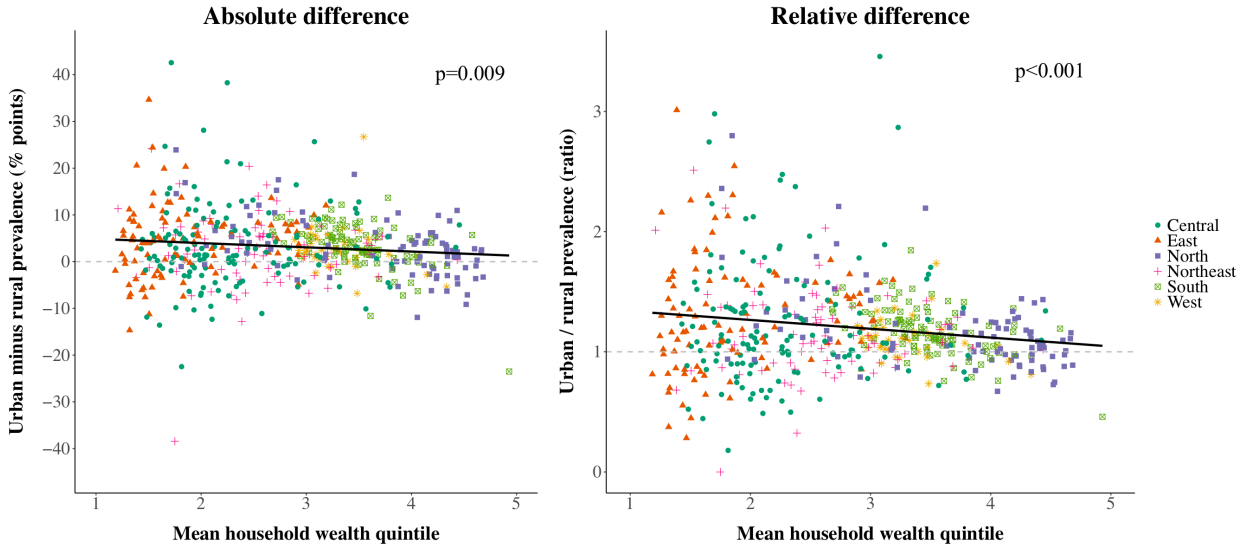


Figure 2.3. Association of the district-level mean household wealth quintile with the difference in the age-standardized prevalence of hypertension between urban and rural areas in a district[1,2,3,4,5]

[1] 'Absolute difference' refers to the hypertension prevalence in urban areas in a district minus the hypertension prevalence in rural areas in a district.

[2] 'Relative difference' refers to the hypertension prevalence in urban areas in a district minus the hypertension prevalence in rural areas in a district.

[3] p-values refer to the statistical significance of the linear (ordinary least squares) regression line (shown in black).

[4] Districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]

[5] The dashed grey line indicates the absence of a difference in hypertension prevalence between urban and rural areas (absolute difference of zero percentage points and a relative difference of one).

Discussion

This first nationally representative study of hypertension in India found an age-standardized prevalence of 24.5% (24.3 – 24.6) among males and 20.0% (19.9 – 20.1) among females. While still within the uncertainty intervals, these figures are lower (particularly among women) than the modeled estimates by the WHO/Non-Communicable Disease Risk Factor Collaboration (NCD-RisC) for India for 2015 (26.5% [21.2 – 32.4] among males and 24.7% [19.9 – 29.9] among females), which used the same definition of hypertension as was used in this study.[93,94] More strikingly, as plotted in **eFigure2**, we found a substantially *higher* prevalence of hypertension among age groups below 45 years and a *lower* prevalence in older age groups than estimated by WHO/NCD-RisC for South Asia (India contributed 76% of the population of South Asia, as defined by WHO/NCD-RisC).[31,93] In fact, in younger age groups, our prevalence estimates for India were higher than those for Central and Eastern Europe - a region that WHO/NCD-RisC identified as having the highest hypertension prevalence globally.[93,94] An important finding of this study, therefore, is the unexpectedly high prevalence of hypertension among young adults in India, which – if untreated – may result in longer lifetime exposure to this risk factor and higher CVD rates in the future. Additionally, the discrepancy between our empirical findings and the

modeled estimates by WHO/NCD-RisC highlights that sophisticated modeling cannot replace investments into large-scale population-based surveys.

We found that hypertension was common across different states and population groups in India. Refuting the hypothesis that the condition is mainly concentrated among wealthier and more educated groups in the country, hypertension was not substantially associated with education and only weakly associated with household wealth, especially among females. Importantly, the prevalence of hypertension is expected to increase over the coming years among all population groups,[93,95] largely because India's population is aging and urbanizing,[10] and standards of living in the country are increasing.[11] Our findings, therefore, provide much needed new evidence to support a public health approach in India to reduce BP at the population level throughout socio-demographic groups. Nonetheless, such efforts must also be accompanied by screening and treatment programs for hypertension. This study reveals substantial variation in hypertension prevalence between states and rural versus urban location – findings which could be used to inform the planning and targeting of such hypertension-focused primary care efforts.

While, overall, hypertension prevalence in urban areas in India was higher than in rural areas, we found that the difference between urban and rural areas tended to decrease as the standard of living in a district increased. This finding suggests that as districts become wealthier, rural-urban differences in hypertension prevalence disappear. In this respect, our findings are similar to those of a study among adults from a total of 628 communities in 17 countries,[89] in which the investigators found hypertension prevalence to be higher in urban than in rural areas in the four

low-income countries in the study, whereas the reverse tended to be true in the other 13 countries, all of which were middle- or high-income.[89]

Equity concerns have been raised about investing limited financial and human resources for health into CVD screening and treatment in LMICs, as CVD is generally thought to occur more frequently in wealthier than poorer strata of society in these countries.[73,96] For instance, an international effort has been initiated to examine to what degree the world's poorest billion - 58% of whom are estimated to be living in India[76] – suffer from the same NCDs as wealthier billions.[73] The hypothesis of this initiative is that the world's most indigent suffer from different NCDs and that the NCD community's focus on CVD will, therefore, exacerbate inequalities in health between wealth groups.[73,74] However, in this study, we show that the wealth and education gradients in hypertension prevalence are minor, especially when compared to age gradients. Although the evidence base is limited because of a lack of large nationally representative studies,[97] our finding is broadly similar to the socio-demographic variation in hypertension prevalence that has been reported in other LMICs.[98] Prevalence of CVD risk factors by wealth groups, however, can only partially inform these equity-focused policy decisions because of two main limitations. The first is that prevalence estimates do not take into account that CVD events are likely to have more detrimental effects among the poor than the wealthy because poorer individuals tend to have lower access to good quality healthcare services and less financial risk protection.[12,64-68] The second limitation is that examining a single risk factor or disease at a time does not provide information on the relative contribution of the disease to the wealth group's total disease burden. In particular, many areas of India are still facing a substantial infectious disease burden and poor maternal and child health indicators[77] – health problems that

disproportionately affect the poor. Despite these limitations, our finding of a high hypertension prevalence throughout wealth and education groups strongly suggests that the world's poorest billion also have an important CVD burden.

Our study has several limitations, which we tried to address where possible. First, a substantial proportion (18.4%) of adults had a missing value for at least one of the two systolic or diastolic BP measurements. Of these, 91% had a missing value for all four BP values and 87% had a missing consent variable (basic socio-demographic information on these participants was still collected from the household head), suggesting that missing BP measurements were mostly due to some adults being absent at the time of the household visit (rather than refusal to consent or data entry errors). Second, while clinical guidelines generally recommend to confirm high BP measurements at a second patient visit before diagnosing hypertension,[91] this study used BP measurements from only one household visit, which is the standard in population-based surveys, including the WHO STEPwise approaches to surveillance (WHO STEPS) surveys.[99] It is important to note that this study used a 'population-based' rather than a clinical definition of hypertension whereby hypertension was defined purely based on BP measurements and not treatment status (i.e., normotensive adults on hypertensive medication were not counted as hypertensive). This definition of hypertension was chosen because it is the definition used by the WHO for Target 6 of its Global Action Plan for NCDs and by the NCD-RisC group for monitoring hypertension prevalence around the world.[20,93]

In conclusion, the unexpectedly high hypertension prevalence among young adults identified by this study may well be a sign of rising hypertension rates in newer generations. This finding

highlights the urgent need for a major investment into public health approaches to reduce blood pressure at the population level if India is to curb the rise of its CVD epidemic. While hypertension was only weakly associated with household wealth and education, our findings on the important variation in prevalence between states, rural versus urban areas, sex, and age groups should be used to guide the planning and targeting of hypertension-focused primary care efforts.

Given the sheer size of India's population, the magnitude of its CVD epidemic,[31,77] and the impact of CVD on household healthcare expenditures and economic growth,[12,15,16] India's success in addressing CVD risk factors will have an important bearing on the world's ability to achieve the WHO's Global NCD targets as well as the SDGs.[20,33]

Cardiovascular disease risk in India: a cross-sectional study of a nationally representative sample of 800,000 adults

Abstract

Background: Cardiovascular disease (CVD) is the leading cause of mortality in India. Yet, evidence on the population's CVD risk is limited. To inform health system planning and effective targeting of interventions, this study aimed to determine how the prevalence of high CVD risk – and the factors that determine risk – varies among states in India, rural-urban location, and by individual-level socio-demographic characteristics.

Methods: We used two large surveys carried out between 2012 and 2014, which included a nationally representative sample of 797,932 adults aged 30 to 74 years. The main outcome variable was 'high CVD risk' defined as a 10-year CVD risk ≥30%, as computed using the Framingham risk score. The prevalence of CVD risk factors and high CVD risk was examined by state, rural-urban residence, age, sex, household wealth, and education.

Results: Overall, 14.6% (95% CI: 14.4 – 14.8) of females and 31.7% (95% CI: 31.4 – 32.0) of males were at high risk of CVD. High CVD risk was most prevalent in North, Northeast, and South India. While risk was positively associated with household wealth and living in an urban area, high CVD risk was nonetheless common in those aged 50-74 years in the poorest wealth quintile in rural areas (29.3% [95% CI: 28.3 - 30.3] among females and 63.3% [95% CI: 62.2 - 64.3] among males). Smoking was more prevalent in poorer quintiles and rural areas, whereas body mass index, diabetes, and systolic blood pressure were positively associated with wealth and urban location.

Conclusions: Crude 10-year CVD risk in India was approximately twice as high as has been estimated for the population of the United States. High CVD risk was common in middle and old age across all population groups in India. We, however, identified substantial variation between states and socio-demographic groups that can facilitate effective targeting of CVD programs to those most in need. Major investments into targeted CVD prevention, screening, and treatment programs are urgently needed if India is to successfully stem its rising CVD epidemic and achieve the Sustainable Development Goals.

Introduction

Cardiovascular disease (CVD) is the leading cause of mortality worldwide, including in low- and middle-income countries (LMICs).[1] India is estimated to have contributed almost one fifth (18.9%) of the global CVD burden, as measured by disability-adjusted life years (DALYs), in 2015.[2] This proportion is likely to increase in the future for three main reasons. First, India is expected to make the greatest contribution to global population growth of any country until at least 2050.[31] Second, India's population is ageing and urbanising: the share of people over 60 years of age is estimated to more than double from 8.9% to 19.4% between 2015 and 2050,[31] and the percentage of Indians living in cities is projected to grow from 30.9% in 2010 to 50.3% in 2050.[32] Third, the rise in living standards and socio-cultural transitions in India are likely to lead to more obesogenic lifestyles.[11] Studies among South Asian migrants in high-income 'Western' countries suggest that South Asians are more prone to developing CVD, and at an earlier age, when living in obesogenic environments than their local counterparts.[87] In addition to its large burden of illness, CVD is also a major cause of impoverishing household healthcare expenditures in LMICs, and estimated to pose a great macroeconomic burden on societies.[12,15,16]

While the prevalence of important CVD risk factors - including both lifestyle factors (e.g., smoking and diet) and cardiometabolic factors (e.g., hypertension and diabetes) - has been studied in large population-based surveys in India,[19,25,39,64,100,101] studies on predicted CVD risk in India have thus far been restricted to either healthcare facility-based samples or small population-based cohorts in specific locales.[102-109] Understanding the predicted future incidence of CVD in India's population, and how it varies among population groups, is critical for health system planning, and effective targeting of prevention, screening, and treatment, in order to mitigate the potentially crippling health and economic effects of CVD on India and her potential to achieve the Sustainable Development Goals (SDGs).[33]

This study, which uses a nationally representative sample of 797,932 adults aged 30-74 years, aims to quantify the proportion of India's adult population aged 30-74 years that is at high risk of CVD, and to determine how risk varies by state, rural versus urban location, and by individual-level socio-demographic characteristics.

Methods

Data sources:

We pooled data from two large household surveys in India, the District-Level Household Survey-4 (DLHS-4) and the second update of the Annual Health Survey (AHS), both of which were conducted between 2012 and 2014. These two surveys were combined because they i) are jointly representative of the entire population of India, ii) were conducted simultaneously, iii) are both representative at the district level, and iv) used the same questionnaire and methodology to

collect biomarker measurements. The states covered by each of the surveys are shown in **eFigure1** (no areas in India were covered by both surveys).

In both surveys, all non-pregnant household members aged 18 years and older were eligible for blood glucose, blood pressure (BP), height, and weight measurements. Participants' blood glucose was measured using a capillary blood sample (from a finger prick) taken using a handheld blood glucose meter (SD CodeFree), which multiplied capillary blood glucose readings by 1.11 to display their plasma equivalent.[57] Participants were instructed to fast for at least eight hours before the time of the measurement. BP was measured twice, with each measurement ten minutes apart, using an electronic upper arm BP monitor (Rossmax AW150). The sampling procedure of each survey is detailed in **eMethods1**.

Ethics:

This analysis of an existing dataset in the public domain received a determination of "Not Human Subjects Research" by the institutional review board of the Harvard T.H. Chan School of Public Health on 23 November 2016 (protocol number: IRB16-1915).

Outcome variable:

The main outcome variable in this analysis was a 'high CVD risk', which we defined as a 10-year CVD risk greater or equal to 30%. This threshold was chosen because it is the cut-off used in the World Health Organisation's (WHO) Global NCD Targets to decide who is eligible for drug therapy and counseling.[20] We used the Framingham risk score (the version not requiring total cholesterol measurements),[110] the most widely used CVD risk scoring system

internationally, to calculate CVD risk.[21] Although very limited, extant evidence suggests that the Framingham score may underestimate CVD risk in South Asians, particularly among South Asian females.[111] In secondary analyses, we also show results using CVD risk calculated with three other risk scores, which do not require blood lipid measurements, namely: Harvard-NHANES,[23] Globorisk,[22] and the risk score developed by the WHO and International Society for Hypertension (WHO-ISH).[24] While none of these scores have been validated in longitudinal studies specific to South Asian populations, the office-based version of the Harvard-NHANES score has been shown to highly correlate (Spearman's rank correlation coefficient >0.9) in South Asian populations (Bangladesh, Bangalore [India], New Delhi and Chennai [India], and Karachi [Pakistan]) with well-established risk scores that require a blood lipid measurement (the ['laboratory-based'] Framingham risk score, the Athero-Sclerotic Cardiovascular Disease risk calculator [ASCVD], and the Systematic Coronary Risk Evaluation [SCORE]).[112]

All of the four risk scores predict the risk of a fatal or non-fatal CVD event, but each score defines a CVD event differently (**eTable12**). The Framingham risk score uses the broadest,[21] and Globorisk[22] and WHO-ISH[24] the narrowest range of CVD events as outcome. The Globorisk project has calibrated its risk equation to 182 countries, including India, as described by Ueda et al.[22] Similarly, the WHO has calibrated its risk score to each WHO sub-region.[24] The Framingham and Harvard-NHANES risk scores were calibrated to India using the incidence rate (by five-year age group) of peripheral artery disease (Framingham only), ischaemic heart disease, and cerebrovascular disease in 2015 as estimated by the Global Burden of Disease project.[2]

The four risk scores predict CVD risk by sex using the following inputs: age, body mass index (BMI) (except WHO-ISH), presence of diabetes (except Globorisk), current smoking, systolic BP, and treatment for hypertension (except Globorisk and WHO-ISH). Diabetes was defined as having a high blood glucose reading or reporting to be on regular treatment for diabetes. High blood glucose was defined as a reading ≥126 mg/dl if reporting to have fasted, and ≥200 mg/dl if reporting not to have fasted. For systolic BP, we used the average of the two BP readings recorded.

Statistical analysis:

CVD risk was computed for each study participant aged 30 to 74 years. The sample was restricted to this age group because the CVD risk equations used in this study have been developed among adults of this age range only.[21,23,113] Using sampling weights to account for the complex survey design (see **eMethods4**), we then calculated the mean proportion of participants with a high CVD risk at the national level, by state, and by individual-level socio-demographic characteristics. All prevalence estimates are unadjusted for individuals' socio-demographic characteristics (other than age-standardisation). In addition, we used ordinary least squares regressions to regress the natural logarithm of the CVD risk score on socio-demographic characteristics and fixed effects for the primary sampling unit (PSU), i.e., a binary indicator for each PSU to adjust for unobserved differences between PSUs. The natural logarithm of CVD risk was used in these regression models to allow for a more intuitive interpretation of the regression coefficients as percentage changes in CVD risk. The regressions were run separately for males and females because each CVD risk score provides sex-specific risks. Two different regression models were fitted for each CVD risk score (except WHO-ISH because it only

provides risk categories rather than a continuous risk variable[24]) and sex: i) models that only included one socio-demographic characteristic, age group, and PSU-level fixed effects, and ii) models that included all socio-demographic characteristics and PSU-level fixed effects as explanatory variables. Standard errors were adjusted for clustering at the PSU level.

The mean (for BMI and systolic BP) or the prevalence (for diabetes and smoking) of each CVD risk factor was plotted by state and socio-demographic characteristics, to help explain observed patterns in the CVD risk scores. We conducted a complete case analysis. The Global Burden of Disease Project's 2013 population for India was used for age standardisation.[114] Statistical analyses were run in R version 3.3.2 (2016, Vienna, Austria),[62] the WHO-ISH score was calculated using the whoishRisk package,[115] and all figures were created with the ggplot2 package.[63]

Results

Sample characteristics:

Socio-demographic information was available for a total of 1,094,754 adults aged 30-74 years, which includes individuals who were not present at the time of the household visit (as socio-demographic information was collected for all household members from the household head). 797,540 (72.9% [797,540/1,094,754]) survey participants who had all the values for the variables needed to calculate each CVD risk score (i.e., blood glucose, systolic BP, height and weight, age, sex, and smoking status) were included in the analysis. While mean BMI was similar between males and females (22.6 kg/m^2 and 22.3 kg/m^2, respectively), females were more likely to have a BMI <18.5kg/m^2 and a BMI ≥25 kg/m^2 than males (**Table 3.1**). 10.0% (42,066/42,0691) of

females and 10.7% (40,444/376,849) of males had diabetes. Smoking prevalence and mean systolic BP were higher among men than women (27.1% [102,182/376,849] versus 2.6% [10,992/420,691] and 129.1mmHg versus 126.7mmHg, respectively). 56.2% (236,555/420,691) of females and 34.0% (128,183/376,849) of males had not completed primary school and approximately one third of participants lived in urban areas. **eTable13** shows that those who were excluded from the analysis (27.1% of participants) because they had a missing value for at least one of the variables needed to calculate predicted CVD risk, had a similar prevalence of CVD risk factors as those who were included in the analysis.

Table 3.1. Sample characteristics

Characteristic	Females	Males
n	420691	376849
Cardiovascular risk factors		
Age group		
30-34 years	72262/420691 (17.2%)	57874/376849 (15.4%)
35-39 years	71458/420691 (17.0%)	56575/376849 (15.0%)
40-44 years	64453/420691 (15.3%)	55851/376849 (14.8%)
45-49 years	55589/420691 (13.2%)	50610/376849 (13.4%)
50-54 years	49350/420691 (11.7%)	44312/376849 (11.8%)
55-59 years	37064/420691 (8.8%)	36074/376849 (9.6%)
60-64 years	31893/420691 (7.6%)	32639/376849 (8.7%)
65-69 years	23553/420691 (5.6%)	25197/376849 (6.7%)
70-74 years	15069/420691 (3.6%)	17717/376849 (4.7%)
Missing	*0/420691 (0.0%)*	*0/376849 (0.0%)*
Mean BMI in kg/m^2 (SD)	22.6 (4.8)	22.3 (4.1)
Missing	*0/420691 (0.0%)*	*0/376849 (0.0%)*
BMI		
<18.5 kg/m^2	72882/420691 (17.3%)	59100/376849 (15.7%)
18.5-22.9 kg/m^2	183441/420691 (43.6%)	176857/376849 (46.9%)
23.0-24.9 kg/m^2	63412/420691 (15.1%)	64810/376849 (17.2%)
25.0-29.9 kg/m^2	74037/420691 (17.6%)	61241/376849 (16.3%)
≥30.0 kg/m^2	26919/420691 (6.4%)	14841/376849 (3.9%)
Diabetes	42066/420691 (10.0%)	40444/376849 (10.7%)
Missing	*0/420691 (0.0%)*	*0/376849 (0.0%)*
Current smoking	10992/420691 (2.6%)	102182/376849 (27.1%)
Missing	*0/420691 (0.0%)*	*0/376849 (0.0%)*
Mean systolic BP in mmHg (SD)	126.7 (21.3)	129.1 (19.7)

Missing	*0/420691 (0.0%)*	*0/376849 (0.0%)*
Systolic BP		
<120 mmHg	168890/420691 (40.1%)	118408/376849 (31.4%)
120 – 129 mmHg	93055/420691 (22.1%)	92742/376849 (24.6%)
130 – 139 mmHg	66204/420691 (15.7%)	75475/376849 (20.0%)
140 – 179 mmHg	81570/420691 (19.4%)	82312/376849 (21.8%)
≥180 mmHg	10972/420691 (2.6%)	7912/376849 (2.1%)
Current treatment for hypertension	9758/420691 (2.3%)	6501/376849 (1.7%)
Missing	*0/420691 (0.0%)*	*0/376849 (0.0%)*
Socio-demographic characteristics		
Educational attainment		
<Primary School	236555/419492 (56.4%)	128183/375652 (34.1%)
Primary School	50585/419492 (12.1%)	51021/375652 (13.6%)
Middle School	50218/419492 (12.0%)	61050/375652 (16.3%)
Secondary School	40320/419492 (9.6%)	59369/375652 (15.8%)
High School	19675/419492 (4.7%)	32860/375652 (8.7%)
>High School	22139/419492 (5.3%)	43169/375652 (11.5%)
Missing	*1199/420691 (0.3%)*	*1197/376849 (0.3%)*
Urban area	136426/420691 (32.4%)	121112/376849 (32.2%)
Missing	*0/420691 (0.0%)*	*0/376849 (0.0%)*
Wealth quintile		
1 (poorest)	90885/420677 (21.6%)	79275/376839 (21.0%)
2	83537/420677 (19.9%)	74815/376839 (19.9%)
3	80524/420677 (19.1%)	72104/376839 (19.1%)
4	81428/420677 (19.4%)	74609/376839 (19.8%)
5 (richest)	84303/420677 (20.0%)	76036/376839 (20.2%)
Missing	*14/420691 (0.0%)*	*10/376849 (0.0%)*

Abbreviations: %=Percentage; BMI=Body Mass Index; kg=kilogram; m=meter; SD=standard deviation; BP=blood pressure; mmHg=millimeters of mercury.

Cardiovascular disease risk at the national level:

Overall, 14.6% (95% CI: 14.4 – 14.8) of females and 31.7% (31.4 – 32.0) of males were at high risk of CVD (**eTable14**). While this was the case for less than one percent of participants in the age groups 30-34 years and 35-39 years, 73.1% (72.0 – 74.1) of females and 96.9% (96.6 – 97.3) of males in the oldest age group (70-74 years) were at high risk. Among those older than 50 years, 36.1% (35.6 - 36.5) of females and 67.6% (67.1 - 68.1) of males were at high risk of a CVD event in the next ten years. The Framingham risk score yielded similar risk estimates to

Harvard-NHANES, but substantially higher estimates than Globorisk and WHO-ISH (**eTable15**). As an alternative measure of need for treatment and counseling to reduce CVD risk, we are showing the crude proportion of participants who were either current smokers, had diabetes, had hypertension, or who were overweight in **eTable16**.

Cardiovascular disease risk by state:

The state-level prevalence (across all age groups) of a high CVD risk varied from 5.0% (4.5 – 5.6) among females in Assam to 30.4% (28.8 – 32.0) among males in Kerala (**Figure 3.1** and **eTable17**). Among both males and females, high CVD risk was most prevalent in South India (including Goa), the three most Northern states in the dataset (Himachal Pradesh, Punjab, and Uttarakandh), the Northeastern states (except Assam), and the Union Territory of Chandigarh. The variation in CVD risk between states was similar when using Harvard-NHANES, Globorisk, and WHO-ISH (**eFigure15**, **eFigure16**, and **eFigure17**). As shown in **eFigure18**, the age-standardized proportion at a high CVD risk in a state/district was positively associated with the area's standard of living (as measured by the state's/district's mean household wealth quintile).

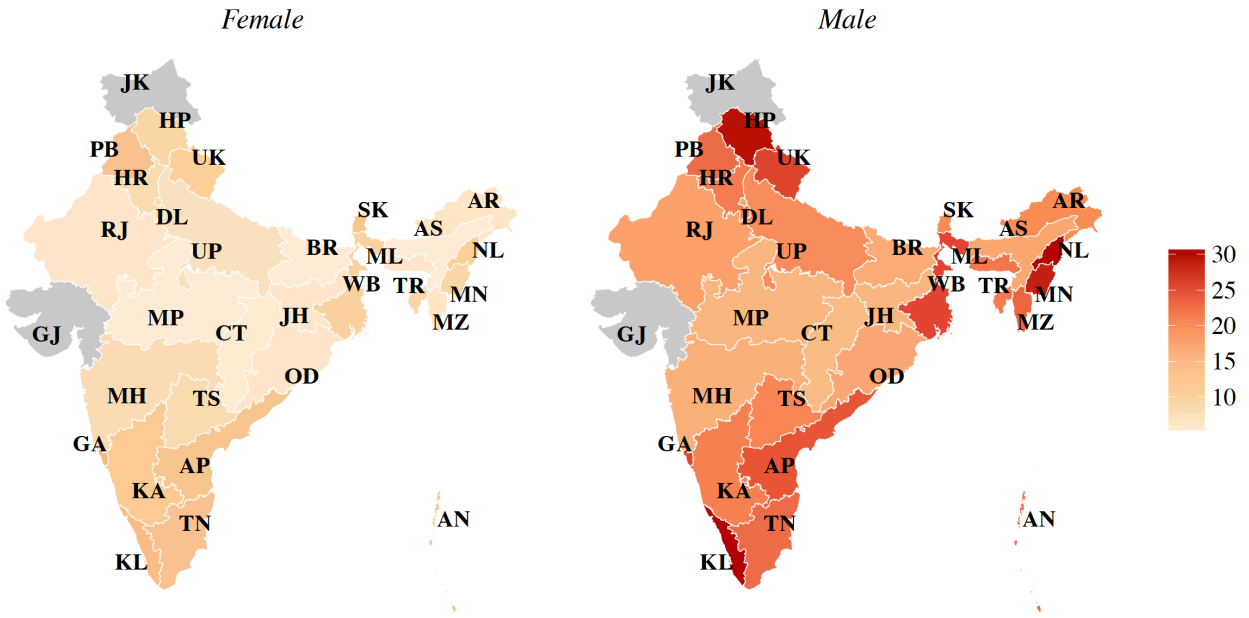


Fig 3.1. Age-standardized prevalence of a high CVD risk, by state[1,2,3,4]

[1] High CVD risk was defined as a 10-year cardiovascular disease risk ≥30% as calculated with the Framingham risk score.

[2] The Union Territories of Chandigarh, Daman and Diu, and Puducherry are not visible in the map due to their small area.

[3] Point estimates and 95% confidence intervals for each state are shown in **eTable17**.

[4] The Global Burden of Disease Project's 2013 population for India was used for age standardisation.[114]

Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CT, Chhattisgarh; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

Figure 3.2 shows differences between states in the age-standardised mean (for BMI and systolic BP) or prevalence (for diabetes and smoking) for each of the cardiovascular risk factors that are included in the CVD risk score. Mean BMI was high in both Northern (Haryana, Himachal

Pradesh, Punjab, and Uttarakhand) and Southern states (Andhra Pradesh, Goa, Karnataka, Kerala, Tamil Nadu), ranging from 22.8 kg/m^2 among males in Uttarakandh to 25.1 kg/m^2 among females in Punjab. Diabetes prevalence, however, was relatively low in the Northern states (ranging from 4.4% among males in Himachal Pradesh to 10.9% among females in Punjab). Mean systolic BP was highest in the Northern states (ranging from 123.7 mmHg among females in Haryana to 136.2 mmHg among males in Punjab) as well as in Nagaland and Sikkim (130.7 mmHg and 132.8 mmHg among females and 133.6 mmHg and 133.1 mmHg among males, respectively). Smoking was most prevalent among males in the Northeastern states of Arunachal Pradesh (46.4%), Manipur (60.3%), Meghalaya (59.7%), Mizoram (71.7%), and the Eastern state of West Bengal (49.5%). State-level point estimates and CIs for each risk factor are shown in **eTable18**. BMI, diabetes, and systolic BP were all positively associated with standard of living in a state/district (**eFigure19-22**).

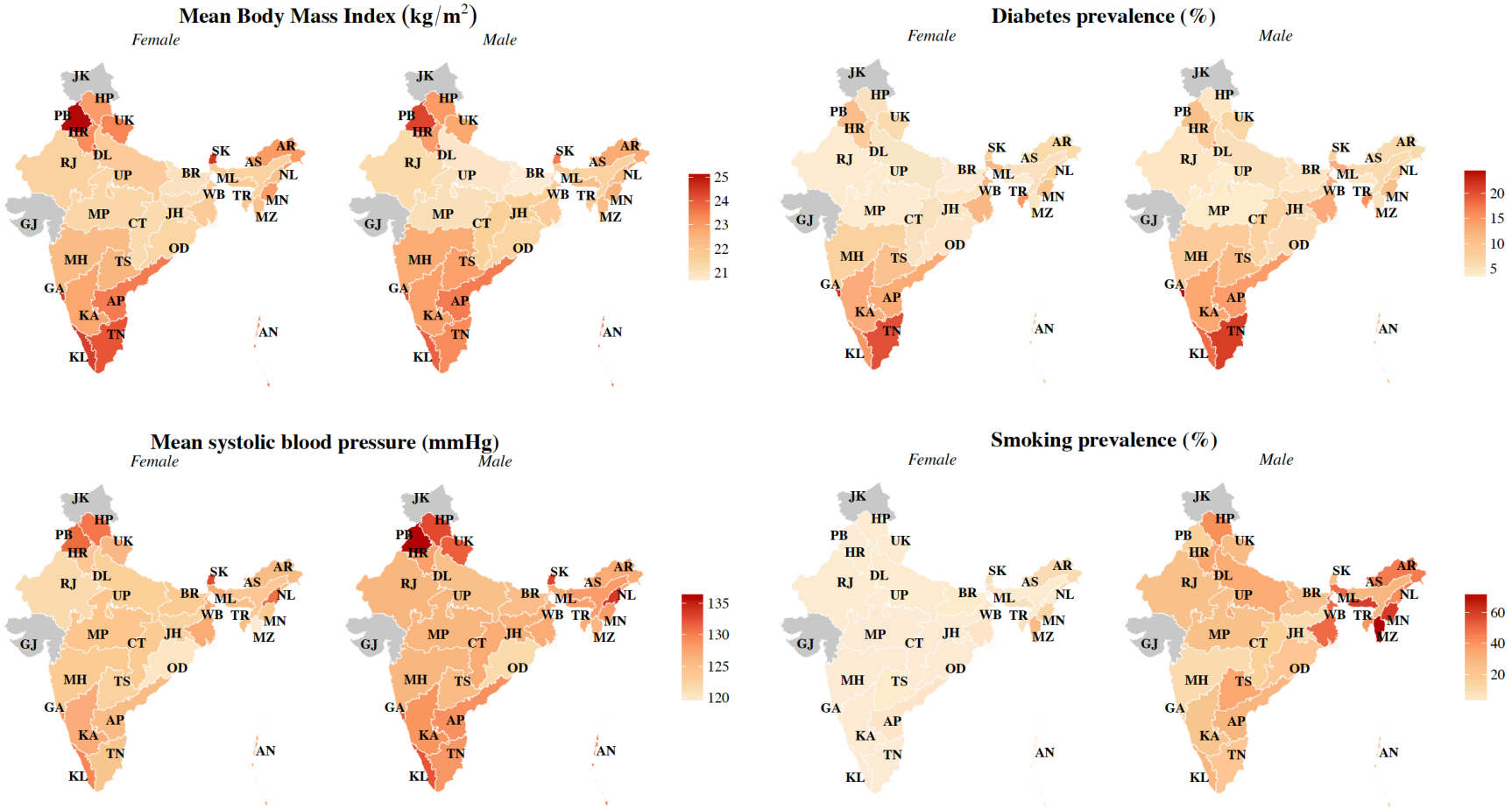


Figure 3.2. Body mass index, diabetes, systolic blood pressure, and smoking prevalence by state[1,2,3,4,5,6]

[1] The prevalence of hypertension treatment was low throughout all states and is thus not shown.

[2] The Union Territories of Chandigarh, Daman and Diu, and Puducherry are not visible in the map due to their small area.

[3] Point estimates and 95% confidence intervals for each state are shown in **eTable17**.

[4] All outcome variables in this figure have been age-standardised using the Global Burden of Disease Project's 2013 population for India.[114]

[5] 'Smoking' refers to smoking of any tobacco products but does not include chewing of tobacco.

[6] Diabetes was defined as a high capillary blood glucose measurement (≥126mg/dl if fasted and ≥200mg/dl if non-fasted) or reporting to be on regular treatment for diabetes.

Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CT, Chhattisgarh; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

Cardiovascular disease risk by individual-level socio-demographic characteristics:

Stratifying the prevalence of high CVD risk by age group, sex, rural versus urban location, and wealth quintile shows that i) those living in urban areas generally had higher mean CVD risk than those living in rural areas, ii) irrespective of sex and location, having a high CVD risk was more common in the wealthiest than in the poorest quintile in all age groups (except the youngest age category), and iii) both the relative and absolute differences in the prevalence of high CVD risk between wealth quintiles were larger in rural than in urban areas (**Figure 3.3**). These patterns were generally similar when using Harvard-NHANES, Globorisk, or WHO-ISH instead of the Framingham risk score (**eFigure23-25**).

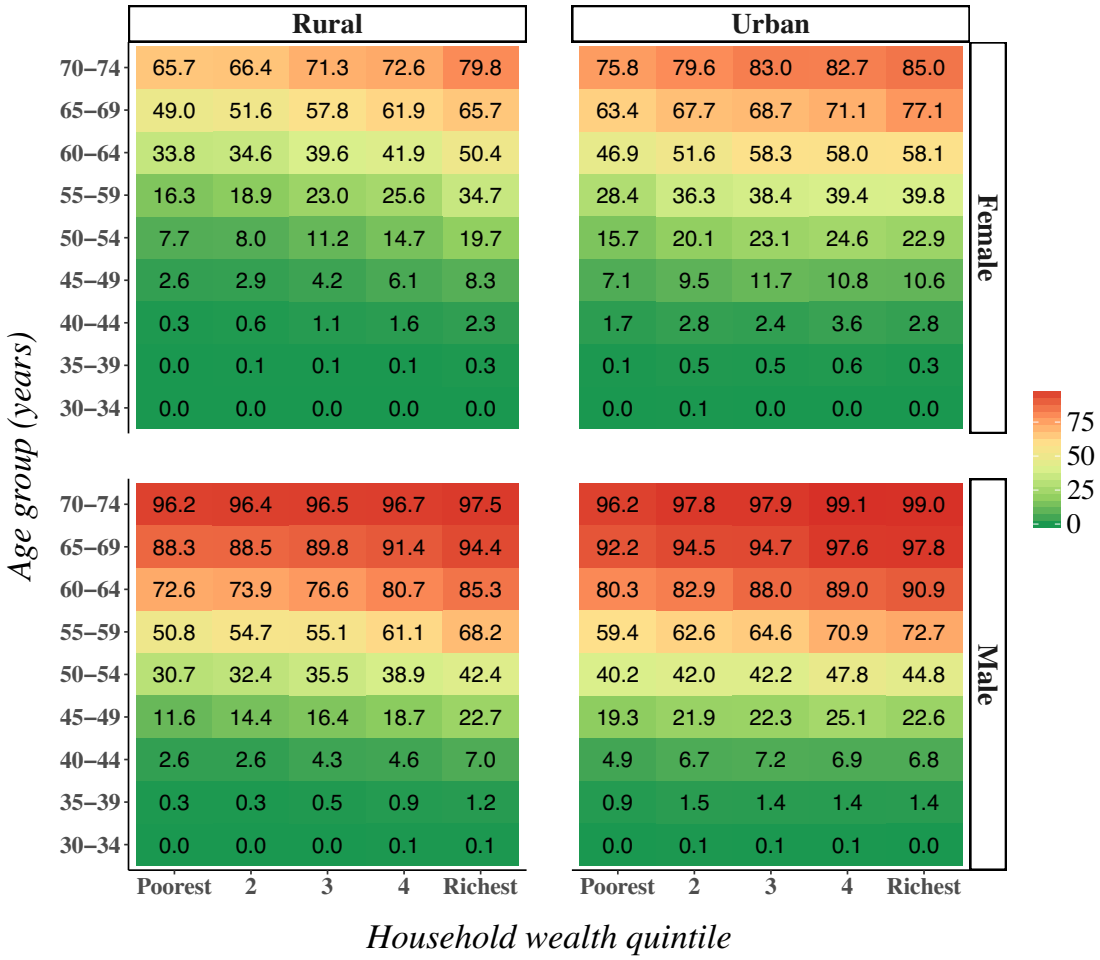


Figure 3.3. Percentage of population with a high (≥30%) 10-year cardiovascular risk by household wealth quintile, age group, rural versus urban location, and sex.[1]

[1] This is the crude prevalence (disaggregated by household wealth quintile, age group, rural-urban residence, and sex) of a high (≥30%) 10-year CVD risk as computed with the Framingham risk score.

Table 3.2 shows the regression coefficients (which can be interpreted as approximations of the percentage change in CVD risk) when regressing the natural logarithm of the Framingham risk score on individuals' socio-demographic characteristics. Household wealth quintile, education, and living in an urban area were positively associated with CVD risk among both sexes, but for all three variables, the coefficients for males were substantially smaller than those for females. The association between education and CVD risk was weak, once the regressions were adjusted for other socio-demographic characteristics. The regression results were similar when using Harvard-NHANES and Globorisk (**eTable19** and **eTable20**).

Table 3.2. *Ordinary least squares regressions of the natural logarithm of cardiovascular disease risk on socio-demographic covariates and PSU-level fixed effects*[1]

	Female (n= 420691)				Male (n=376849)			
	Adjusted for age group only[2]		Adjusted for all covariates[3]		Adjusted for age group only[2]		Adjusted for all covariates[3]	
	Coefficient[4] *(95% CI)*	*P*	*Coefficient*[4] *(95% CI)*	*P*	*Coefficient*[4] *(95% CI)*	*P*	*Coefficient*[4] *(95% CI)*	*P*
Wealth quintile								
1 (poorest)	Ref.		Ref.		Ref.		Ref.	
2	2.55 (2.06, 3.04)	<0.0001	2.23 (1.74, 2.72)	<0.0001	1.06 (0.62, 1.49)	<0.0001	0.97 (0.53, 1.41)	<0.0001
3	5.18 (4.66, 5.70)	<0.0001	4.93 (4.40, 5.45)	<0.0001	2.45 (1.98, 2.91)	<0.0001	2.55 (2.08, 3.02)	<0.0001
4	8.57 (8.04, 9.09)	<0.0001	8.18 (7.64, 8.72)	<0.0001	4.43 (3.96, 4.90)	<0.0001	4.53 (4.04, 5.02)	<0.0001
5 (richest)	15.20 (14.67, 15.73)	<0.0001	14.66 (14.08, 15.24)	<0.0001	9.12 (8.64, 9.60)	<0.0001	9.12 (8.60, 9.64)	<0.0001
Educational attainment								
<Primary School	Ref.		Ref.		Ref.		Ref.	
Primary School	6.55 (6.07, 7.03)	<0.0001	4.20 (3.71, 4.68)	<0.0001	1.96 (1.53, 2.38)	<0.0001	0.96 (0.54, 1.39)	<0.0001
Middle School	7.33 (6.84, 7.82)	<0.0001	3.90 (3.39, 4.40)	<0.0001	3.16 (2.75, 3.56)	<0.0001	1.49 (1.08, 1.90)	<0.0001
Secondary School	10.05 (9.51, 10.59)	<0.0001	4.66 (4.09, 5.22)	<0.0001	4.72 (4.30, 5.14)	<0.0001	1.87 (1.43, 2.30)	<0.0001
High School	8.94 (8.20, 9.67)	<0.0001	2.51 (1.74, 3.27)	<0.0001	3.72 (3.21, 4.24)	<0.0001	0.24 (-0.30, 0.77)	0.39
>High School	7.96 (7.25, 8.67)	<0.0001	-0.61 (-1.37, 0.15)	0.12	6.29 (5.81, 6.77)	<0.0001	1.29 (0.77, 1.82)	0.002
Geography								
Rural	Ref.		Ref.		Ref.		Ref.	
Urban	10.25 (9.66, 10.84)	<0.0001	10.90 (10.29, 11.51)	<0.0001	8.15 (7.63, 8.67)	<0.0001	8.68 (8.15, 9.22)	<0.0001

Abbreviations: CI=Confidence Interval; PSU=primary sampling unit; Ref. = Reference category.

[1] Standard errors were adjusted for clustering at the household level.

[2] These models included one sociodemographic characteristic, age group, and a binary indicator variable for each PSU as explanatory variables.

[3] This model included all variables listed in the table, age group, and a binary indicator for each PSU as explanatory variables.

[4] Coefficients were multiplied by 100 so that they can be interpreted as an approximation of the percentage change in cardiovascular risk associated with a one unit change in the explanatory variable.

Figure 3.4 shows that while mean BMI, diabetes, and mean systolic BP were all positively associated with household wealth and living in an urban area, the prevalence of diabetes and

mean systolic BP were nonetheless high in middle- and old-age among the poorest wealth quintiles and in rural areas. Smoking, on the other hand, was more common in poorer quintiles, in rural areas, and among males.

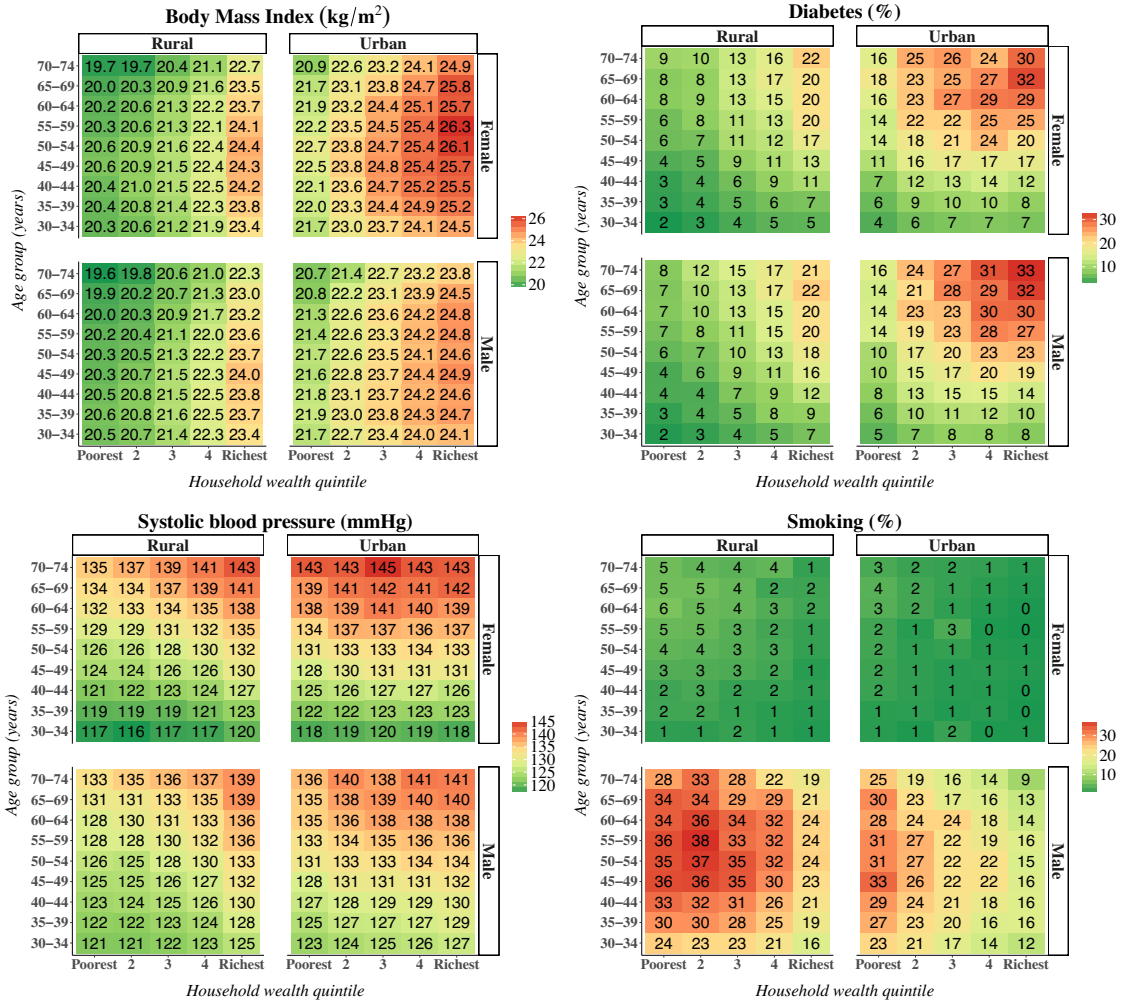


Figure 3.4. Mean body mass index, diabetes and smoking prevalence, and mean systolic blood pressure by rural versus urban residence, sex, and household wealth quintile.

[1] These are crude (not age-standardised) estimates.

[2] 'Smoking' refers to smoking of any tobacco products but does not include chewing of tobacco.

[3] Diabetes was defined as a high capillary blood glucose measurement (≥126mg/dl if fasted and ≥200mg/dl if non-fasted) or reporting to be on regular treatment for diabetes.

Discussion

By pooling and analyzing data on CVD risk that are nationally representative for India (accounting for more than a sixth of the world's population[31]), we found that the predicted 10-year CVD risk in India was high. In fact, it was roughly twice as high as the estimates for the United States (US) even though the US population is substantially older than that of India.[10] In the (nationally representative) US National Health and Nutrition Examination Survey (NHANES) conducted in 2009-2010, the mean crude 10-year CVD risk (using the Framingham risk score) among those aged 30-74 years was 11.5% (95% CI: 10.7 - 12.3) among males and 6.2% (95% CI: 5.8 - 6.6) among females.[116] By comparison, in the same age range and using the same risk score, mean crude 10-year CVD risk in our study was 21.4% (21.3 - 21.6) among males and 12.7% (95% CI: 12.7 - 12.8) among females. Both systolic BP and smoking prevalence were higher in this sample than in NHANES. The study of NHANES, however, excluded participants with a previous or current CVD event, which were unable to do in this dataset due to lacking questionnaire data on CVD. The high predicted CVD risk in this study is particularly concerning given evidence from several studies that the Framingham risk score may underestimate risk in South Asian populations.[111]

We found that having a high CVD risk is common in middle- and old-age across most states and population groups in India, including the rural poor. While age was the strongest determinant of CVD risk in this analysis, we identified important variation in risk among states (with CVD risk being highest in the Northern, Northeastern, and Southern states) and by individuals' socio-demographic characteristics. Regarding the latter, we found that i) CVD risk was higher in urban areas and among males; ii) while mean BMI was substantially higher among the wealthy than the

poor, diabetes and high systolic BP were common among the poor in middle and old age, and iii) smoking was most prevalent among poorer wealth quintiles and in rural areas. Thus, while a major investment in CVD and risk factor prevention, screening, and treatment is needed across India, this study provides important insights to effectively target health system resources for CVD management to those most in need.

The risk estimates obtained with the Framingham and Harvard-NHANES score were substantially higher than those obtained using Globorisk and WHO-ISH. This observed difference in estimates was expected given that Globorisk and WHO-ISH predict the risk of (fatal or non-fatal) myocardial infarction or stroke, while Framingham and Harvard-NHANES include a broader set of outcomes. For its global NCD target that "at least 50% of eligible people receive drug therapy and counselling to prevent heart attacks and strokes" by 2020, the WHO defined eligibility as a 10-year CVD risk ≥30%.[20] The large differences between risk scores observed in this study indicate that such a target is difficult to operationalise unless the risk score used to define eligibility is also specified.

This study has several limitations. First, we had to rely on 'office-based' risk scores that used BMI instead of cholesterol measurements. However, in an analysis of nine cohorts from ten LMICs, Gaziano et al. have shown that the office-based version of the Harvard-NHANES score performed virtually as well in predicting CVD events as the laboratory-based versions of ASCVD, Framingham, and SCORE.[112] Similarly, although Ueda et al. noted that the office-based Globorisk score underestimated risk among those with diabetes, they found that it classified more than 80% of participants correctly into low and high CVD risk.[22] Second, a

relatively high percentage (27.1%) of participants had a missing value for at least one variable needed to calculate their CVD risk. While we show that participants excluded because of a missing value had similar summary statistics for CVD risk factors as those included in the analysis, there is nonetheless potential for selection bias. Third, a one-time capillary blood glucose measurement is not recommended for the diagnosis of diabetes in clinical settings.[79] However, this screening method has been shown to have an acceptable sensitivity and specificity for defining diabetes in population-based research, and is hence the recommended method for monitoring diabetes prevalence in the WHO's STEPwise Approach to Non-communicable Disease Risk-Factor Surveillance.[80-82] Lastly, the Framingham risk score (and other CVD risk scores developed among Caucasian populations) may underestimate CVD risk, particularly among South Asian females.[117] A related note of caution is that the CVD risk scores used here do not take into account consumption of smokeless tobacco, which is common in India and may increase CVD risk.[118,119]

In conclusion, crude 10-year CVD risk in India is high and was common throughout socio-demographic groups in middle and old age. We identified important variations in CVD risk and risk factor prevalence between states and population groups – information that will be essential for effective targeting of resources and interventions for prevention, screening, and treatment to those most in need. Given the detrimental effects of CVD on health,[2] financial risk protection,[12] and economic growth,[16] India's performance in tackling its CVD epidemic will directly impact several SDGs (e.g., SDG 1: "End poverty in all its form everywhere" and SDG 3: "Ensure healthy lives and promote well-being for all at all ages") and corresponding targets (SDG 3.4: "By 2030, reduce by one third premature mortality from NCDs" and SDG 3.8 on achieving

universal health coverage). Considering the size and growth of its population,[31] the country's performance in addressing its CVD epidemic will also have a decisive impact on the *world*'s ability to achieve the SDGs.[33]

Conclusion

Main findings:

The analyses presented in this dissertation reveal that: i) there is important variation in the prevalence of CVD risk factors by state, urban-rural residence, sex (except diabetes), and age; ii) relative wealth differences are substantial for diabetes but less so for hypertension and CVD risk; iii) differences in prevalence of each outcome by education are small once adjusted for age; iv) the poor have an important CVD risk factor prevalence, especially in urban areas, among males, and among older adults; v) absolute CVD risk differs greatly between risk scores highlighting that any goal or recommendation based on CVD risk must specify the risk score to be used; and vi) both diabetes and hypertension prevalence in a district are positively associated with the district's standard of living (although for diabetes, this association is not present in the wealthiest quintile).

Contributions of this dissertation to the literature:

This dissertation makes several important contributions to the existing literature on CVD risk in India. First, the national prevalence estimates obtained from this study are free from any extrapolation or simulation as they are obtained from the first nationally representative analysis of these outcomes (diabetes, hypertension, and predicted CVD risk) in India. Second, this study is the first to provide empirical prevalence estimates on these outcomes for every state of India (with the exception of Gujarat, and Jammu and Kashmir). Third, unlike existing "national" studies (e.g., NCD RisC and the Global Burden of Disease), which use sophisticated modelling techniques to arrive at national prevalence estimates, this study was able to examine the association between the outcomes and *individual-level* socio-demographic characteristics (as

opposed to, for example, the Global Burden of Disease study's socio-demographic index, which is an area-level measure of development). Fourth, unlike the INDIAB study,[19] this dissertation employs PSU-level fixed effects in its regressions and thus examines the association of individual-level socio-demographic characteristics with the outcomes within areas. In a country as large and diverse as India, it seems statistically more appropriate to compare people within small areas rather than pooling them across the entire country and ignoring area-level effects on the outcomes. We, therefore, believe this is an important strength and contribution of this dissertation to the literature. Fifth, this dissertation is the first to use large-scale population-based data from India to calculate a predicted CVD risk.

Comparison to existing prevalence estimates:

This study provides new prevalence estimates for diabetes, hypertension, and high CVD risk for India. **Table 4.1** lists existing prevalence estimates for diabetes and hypertension from studies that were conducted in more than one state of India and aimed to be representative either for the entire state, or all rural or urban areas in a state. The diabetes prevalence estimates in this study were lower than existing national estimates obtained from published studies that use modeling as the basis of their prevalence estimation.[83,120,121] However, state-level prevalence estimates were similar to those reported in the largest sub-national study of diabetes to date (the ICMR-INDIAB study).[19] It is important to note that we did not count as diabetic those who are on diabetes treatment and have achieved a normal blood glucose. Our prevalence estimates for diabetes are therefore likely to be an underestimate of true diabetes prevalence. With regards to blood pressure, this study's hypertension prevalence estimate was lower than that estimated by NCD-RisC.[93] However, as detailed in Paper 2, we found a higher prevalence in younger age groups

than NCD-RisC had estimated. I did not identify any studies that report a predicted CVD risk in a population-based sample representative for at least one state of India.

Policy implications:

This dissertation has three main policy implications. First, by showing how CVD risk factors and composite risk varies among population groups in India, our analyses can inform targeting of relevant prevention, screening, and treatment programs. Specifically, our findings on the important variation of diabetes, hypertension, and predicted CVD risk between states and by urban-rural location can guide policy makers where geographically CVD risk reduction programs should be implemented. In addition, the variation in prevalence of diabetes, hypertension, and CVD risk by household wealth can inform policy makers and program managers on the type of households and neighborhoods that should be targeted with CVD-related programs. Lastly, the variation in CVD risk by individual-level socio-demographic characteristics (e.g., age) can guide what patients at healthcare facilities and individuals within households (e.g., during household visits by community health workers) should be offered relevant screening services. Second, by providing a granular assessment of the current need for care for diabetes and hypertension, as well as the predicted risk of a CVD event (and thus future need for CVD care) in the coming ten years, this dissertation can inform the planning of relevant health system functions. Third, this thesis examines how prevalence of these conditions varies among socio-economic groups and can thus (albeit with the limitation that we do not have data on the total disease burden by socio-economic groups) contribute to discussions on the degree to which a policy focus on CVD in India might exacerbate current inequalities in health between socio-economic groups.

Limitations:

An important limitation of this dissertation is the measurement of the outcome variables. Specifically, for both diabetes and hypertension, only participants who reported having experienced any symptoms lasting for more than one month in the last year were asked about diabetes and hypertension diagnosis and treatment. This limitation implies that the prevalence estimates obtained in this analysis (based on having a high blood glucose/pressure only in papers 1 and 2) are likely lower than those from studies that defined these conditions based on having either a high blood glucose/pressure or reporting to be on treatment for the condition. In addition, since it is probable that wealthier individuals are more likely to be on antidiabetic and/or antihypertensive treatment than poorer participants, the wealth gradients observed in this dissertation are likely shallower than they would have been had full treatment information been available and included in the definition of the condition. However, defining these conditions based on having a high blood glucose/pressure only can be viewed as a measure of (unmet) need for control of the condition (as those who have achieved diabetes/hypertension control were not considered to be diabetic/hypertensive). A further limitation specific to the diabetes outcome is that diabetes was defined based on fasting blood glucose only. In a study of 96 population-based surveys, NCD-RisC has shown that defining diabetes based on fasting blood glucose only, compared to defining the condition based on a high fasting plasma glucose or two-hour oral glucose tolerance test, leads to a somewhat lower (by 2-6 percentage points) diabetes prevalence.[122] A third limitation is that the only measures of socio-economic position in Indian society available in the AHS and DLHS-4 were data on household assets and characteristics (from which I created an asset index – referred to as 'household wealth index' in this dissertation) and educational attainment. Notably, there was no data on consumption expenditure

or household income. The household wealth index has been criticized for having only modest inter-observer and test–retest reliability.[123] In addition, some have argued that data should not merely be collected on ownership of durable goods but also on their quality and nature.[124] Nonetheless, the asset index is a widely used indicator of household wealth having, for instance, been employed in virtually all Demographic and Health Surveys.[125] There is no particular reason why the asset index would be less appropriate for India as compared to other LMICs given that asset indices are widely used in middle-income countries and even high-income countries, such as for the European Union's 2020 poverty measure and the Dutch Life Situation Index.[125-127] Indeed, India was the country for which Filmer and Pritchett originally developed the asset index in their seminal study from 2001.[58]

Future research:

Future nationally representative studies of CVD risk factors in India should not only collect biomarker data but also include a rigorous set of questions on previous screening, awareness of diagnosis, reception of lifestyle advice, and current as well as past treatment for these conditions. Such data will provide a more comprehensive assessment of the unmet need for care of diabetes and hypertension, and thus be more informative to clinicians and policy makers. In addition, future studies may consider asking questions on consumption expenditure to allow for an alternative and arguably more accurate assessment of poverty. Specific to diabetes, future surveys should consider conducting a two-hour oral glucose tolerance test (OGTT) among at least a subsample of the participants as was done in INDIAB.[19] With regards to predicted CVD risk, there is an urgent need for developing and validating CVD risk scores in South Asian cohort

studies given that it appears likely that a cohort in, for example, Framingham (Massachusetts, USA) can hardly be generalized to populations across the world.

More generally, moving forward, India will need to improve its monitoring of NCDs to have access to reliable and timely information on the need for NCD prevention, screening, and treatment. Being able to monitor trends over time will require that conditions are assessed using the same method(s) across survey rounds. This point is of particular import to the monitoring of diabetes prevalence given that that the use of different biomarkers for diabetes has been shown to result in substantially different prevalence estimates.[122] A simple and effective approach in this regard could be to add a comprehensive NCD module (including biomarker measurements) to the National Family Health Survey (NFHS) rounds, and to conduct these rounds more frequently (e.g., every five years). The fact that the latest round of the NFHS (the NFHS-4) is set to be the first to provide biomarker-based data on diabetes and measure BP is certainly a step in this direction.[55] However, the quality of the data and survey instruments remains to be verified as the data have not yet been released into the public domain. Making such data available to the public in a timely manner - both for the purposes of transparency and to allow international and local researchers to gain insights from these large and expensive surveys - is crucial. Unfortunately, it took 55 months after completion of data collection for the AHS microdata to be made available in the public domain;[55] and this was done without an individual identifier to allow merging of data across AHS datasets.

Lastly, Indian policy makers will need to design and evaluate models to improve screening for diabetes and hypertension. Relatedly, those who are screened ‘positive’ will need to be

successfully linked to care and, those whose diagnosis is confirmed, retained in care long term. Among other examples, the global health community's experience in this regard with HIV demonstrates that retaining patients along this chronic disease care continuum is a great challenge.[128] Moving forward, India will therefore need to identify effective healthcare delivery models that can feasibly be scaled up to improve linkage to, and retention in care. Encouragingly, India's public health community has already embarked on this challenge with several randomized trials of novel healthcare delivery models to improve care linkage, care retention, and/or medication adherence being currently underway or having been recently completed.[129-134] In particular, it may be possible to leverage India's large existing community health worker cadre – the Accredited Social Health Activists (or 'ASHA') – as well as the country's rural child care centers (Anganwadis) and their staff to support primary care efforts for diabetes and hypertension. This is a promising possibility that the DISHA trial is currently investigating.[132] Undoubtedly, however, the next hurdle will be to successfully translate the findings of these trials to policy. In addition to experimentation with new healthcare delivery models, the country's public health community will also need to gather more evidence on primary prevention approaches for CVD. Currently, the effects of primary prevention policies in India, such as taxes on tobacco, palm oil, and sugar-sweetened beverages, have relied on modelling studies only.[135-138]

Conclusion:

While we identified important variation in the prevalence of diabetes, hypertension, and high CVD risk among states and by rural-urban location, prevalence levels in India are high across all geographic settings and socioeconomic groups in middle and old age. Major investments in

targeted CVD risk prevention, risk factor detection, and treatment programs are needed across the country if India is to avert catastrophic health, social, and economic consequences of these conditions and their sequelae. Given the size, growth, rapid urbanization, and aging of India's population,[31,32] as well as the high levels of impoverishing healthcare expenditures caused by NCDs,[12] the country's success in tackling its diabetes and hypertension epidemic will be crucial to achieving Sustainable Development Goals globally.

Table 4.1 *Previously published diabetes and hypertension prevalence estimates for India.*

Study name/Organization	Representativeness	Year(s) of data collection	Prevalence findings	Socio-demographic variation in prevalence	Reference
Diabetes					
ICMR-INDIAB	15 states of India	2008-2015	7.3% (7.0–7.5) [standardized to the India census 2011]	Higher prevalence in urban areas, those with a higher socio-economic status (in rural areas), males, and older individuals.	[19]
IDF Diabetes Atlas	Modelled estimates aiming for national representativeness	Estimates for 2015	9.3% (7.6 - 11.4) [standardized to the WHO reference	Not reported	[83]

			population]		
Global Burden of Disease Study	Modelled estimates aiming for national representativeness	Estimates for 2015	6.5% (6.0-7.1) among the entire population (including children)	Not reported	[84]
NCD RisC	Modelled estimates aiming for national representativeness	Estimates for 2014	9.1% (5.2 to 14.2)	Not reported	[120]
National Nutrition Monitoring Bureau's Third Repeat Survey	Rural areas in 10 states	2011-2012	Men: 8.2% (7.7-8.7); Women: 6.8% (6.4-7.2)	Higher among men, older individuals, and those without formal education; no association with occupation.	[38,39]

Hypertension

NCD RisC	Modelled estimates aiming for national	Estimates for 2016	26.5% (21.2 – 32.4) among males and 24.7%	Not reported	[93]

	representativeness		(19.9 – 29.9) among females [age-standardized to the WHO reference population]		
National Nutrition Monitoring Bureau's Third Repeat Survey	Rural areas in 10 states	2011-2012	22.2% (21.7 – 22.8) among men and 21.6% (21.1 – 22.1) among women	Higher among older individuals and those without formal education	[38,39]
SAGE	Representative for adults aged ≥50 years in six Indian states	2007-2008	23% (no CI given) [age-standardized using the United Nations Development Program's world population pyramid]	Higher among older individuals, in urban areas; no clear trends by wealth quintile or education; no difference by sex	[64]

Supplementary Appendix

eMethods1. Methodology of the AHS and DLHS-4

We pooled data from two large household surveys in India: The District-Level Household Survey-4 (DLHS-4) and the second update of the Annual Health Survey (AHS). eFigure1 shows the states and Union Territories covered by each survey. Both surveys are representative at the district level. They jointly cover all 29 states of India except Jammu and Kashmir (data were not collected due to violent conflicts) and Gujarat (data were not available in the public domain), and five of India's seven Union Territories (data were not available for Dadra and Nagar Haveli, and Lakshadweep). The two states and two Union Territories not included in this analysis only accounted for 6% of India's population in 2011 (the time of the last census).[35] Both surveys administered a questionnaire to the household head to ascertain socio-demographic information for each household member (regardless of whether the individual was present or absent at the time of the interviewer's visit), and measured blood glucose (BG) and blood pressure (BP) in each household member aged 18 years and older. All participants were asked to fast overnight until the time of the BG measurement in the morning. BG was measured once using the SD CodeFree handheld glucometer. BP was measured twice in the left upper arm (with the patient sitting) using an electronic BP monitor (Rossmax AW150). Data collectors were instructed to ensure a gap of at least three minutes between BP measurements. As part of the standard protocol, participants were asked to place their left arm on a flat surface (palm facing up) with the center of the upper arm being at approximately the same height as the heart, and instructed to refrain from talking during the measurement.

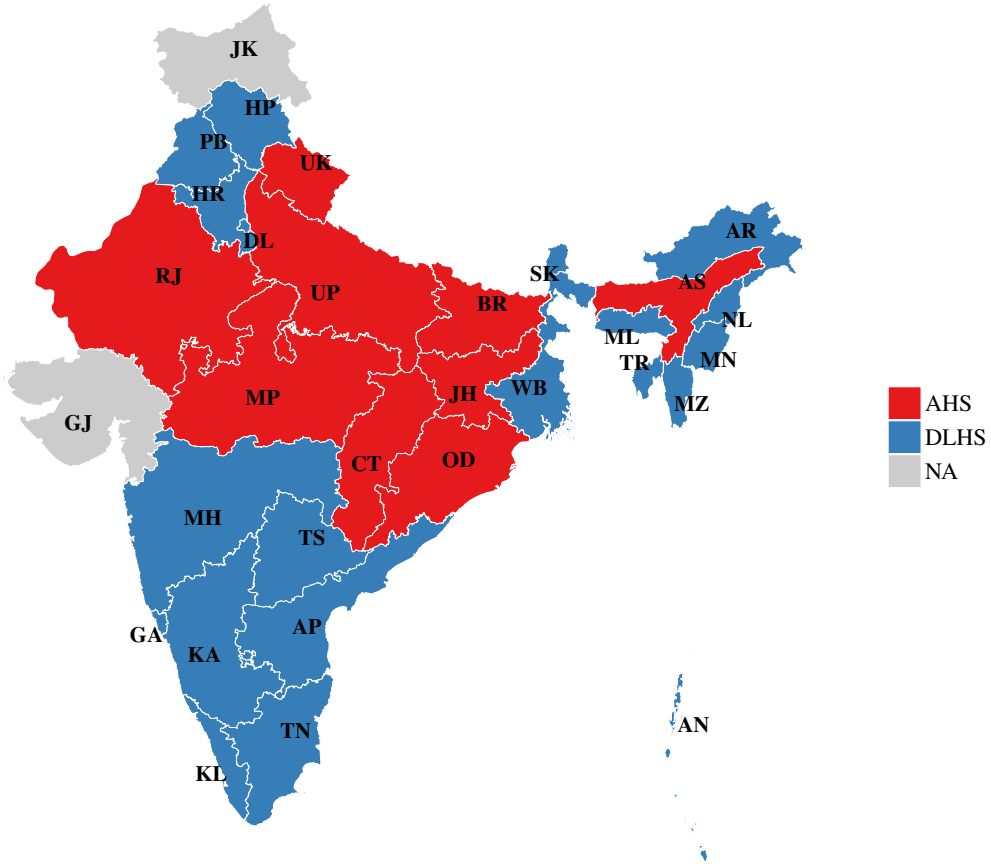
Annual Health Survey:

Data for the AHS were collected between 2012 and 2013 in all 284 districts of nine states of India, which were selected because they had the highest rate of infant and child mortality in the country in 2010.[55] The two-stage cluster random sampling design of the AHS was self-weighting at the district level. In the first stage, villages in rural areas and census enumeration blocks in urban areas were selected through simple random sampling with probability proportional to population size (using projections from the 2001 India Census). In the second stage, households were selected through systematic random sampling (sampling the first household randomly, and then selecting every alternate household). The AHS dataset containing participants' socio-demographic information was merged with the dataset containing BP measurements as outlined in eMethods2.

District-Level Household Survey-4:

Data for the DLHS-4 were collected between 2012 and 2014 in all 336 districts of 18 states and five Union Territories (also referred to as 'states' in the manuscript) of India.[55] In the first stage, census villages in rural areas were selected through probability proportional to population size (again, using projections from the 2001 India Census), and urban frame survey blocks in urban areas through simple random sampling. In the second stage, households were selected through systematic random sampling.[90]

eFigure1. States and Union Territories covered by each survey[a]



[a] The Union Territories, Chandigarh, Daman and Diu, and Puducherry, which were all covered by the DLHS-4, are not visible in the map due to their small area.

Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CT, Chhattisgarh; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal

eMethods2. Matching Annual Health Survey biomarker data to participants' socio-demographic data

Annual Health Survey (AHS) data in the public domain does not have a unique identifier that allows for merging of the 'laboratory dataset', which contains BG and BP measurements, to the dataset that contains respondents' full socio-demographic information. We thus merged these datasets using an indicator composed of the state, district, stratum (indicating rural versus urban location and village size), a household identifier that is unique within each primary sampling unit, and a household member serial number given during data entry as well as one assigned after data entry.

607,227 out of 1,028,545 (59.0%) non-pregnant adults in the laboratory dataset were successfully matched to their corresponding socio-demographic information. As detailed in the tables below, participants who were not matched had similar characteristics as those who were matched. Participants were merged independently of whether their BG or BP measurement was missing.

Across all nine AHS states:

Variable	**Matched**	**Not matched**
	n=607,227	*n=421,318*
Male (%)	50.7	48.4
Age (mean ± SD)	40.8±15.9	38.9±17.0
Diabetes (%)	7.0	6.3
Plasma glucose in mg/dl (mean ± SD)	108.4±21.7	108.0±21.3
Hypertension (%)	22.3	21.0
Systolic BP (mean ± SD)	123.4±18.9	122.6±19.1
Diastolic BP (mean ± SD)	77.9±12.5	77.3±12.3
Urban (%)	19.4	18.0

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Assam:

Variable	**Matched**	**Not matched**
	n=62,882	*n=23,626*
Male (%)	51.3	44.5
Age (mean ± SD)	40.3±14.9	37.1±16.1
Diabetes (%)	7.5	7.3
Plasma glucose in mg/dl (mean ± SD)	109.4±21.5	108.5±21.3
Hypertension (%)	24.2	19.7
Systolic BP (mean ± SD)	125.7±17.6	123.3±17.5
Diastolic BP (mean ± SD)	79.5±11.8	77.9±11.5
Urban (%)	16.8	19.8

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Bihar:

Variable	**Matched**	**Not matched**
	n=71,861	*n=80,049*
Male (%)	49.6	53.5
Age (mean ± SD)	40.8±15.9	38.3±16.9
Diabetes (%)	6.9	5.3
Plasma glucose in mg/dl (mean ± SD)	106.7±19.8	104.5±18.6
Hypertension (%)	22.7	18.8
Systolic BP (mean ± SD)	123.7±18.6	120.9±17.5
Diastolic BP (mean ± SD)	77.9±12.8	77.2±11.6
Urban (%)	9.6	8.3

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Chhattisgarh:

Variable	**Matched**	**Not matched**
	n=37,579	*n=19,997*
Male (%)	52.6	48.4
Age (mean ± SD)	39.9±14.9	38.8±16.1
Diabetes (%)	8.8	9.2
Plasma glucose in mg/dl (mean ± SD)	110.0±19.2	110.1±21.0
Hypertension (%)	18.1	18.7
Systolic BP (mean ± SD)	123.1±16.5	123.2±17.2
Diastolic BP (mean ± SD)	77.7±11.9	77.5±12.2
Urban (%)	19.1	22.2

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Jharkhand:

Variable	Matched	Not matched
	n=35,721	*n=18,875*
Male (%)	44.8	43.6
Age (mean ± SD)	40.6±15.5	39.1±16.8
Diabetes (%)	6.8	5.4
Plasma glucose in mg/dl (mean ± SD)	105.4±24.8	103.9±21.7
Hypertension (%)	25.0	24.3
Systolic BP (mean ± SD)	123.0±20.0	122.7±19.9
Diastolic BP (mean ± SD)	77.8±13.3	77.5±13.2
Urban (%)	17.6	22.2

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Madhya Pradesh:

Variable	Matched	Not matched
	n=101,896	*n=63,056*
Male (%)	54.4	51.1
Age (mean ± SD)	40.0±15.8	38.9±16.8
Diabetes (%)	6.2	5.4
Plasma glucose in mg/dl (mean ± SD	107.3±20.0	107.3±19.0
Hypertension (%)	21.7	21.2
Systolic BP (mean ± SD)	124.6±18.1	124.3±17.8
Diastolic BP (mean ± SD)	79.8±11.4	79.6±11.1
Urban (%)	32.4	28.9

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Odisha:

Variable	Matched	Not matched
	n=92,000	*n=21,570*
Male (%)	49.2	43.8
Age (mean ± SD)	42.2±16.0	39.2±17.5
Diabetes (%)	7.0	6.4
Plasma glucose in mg/dl (mean ± SD)	107.6±24.0	106.3±23.2
Hypertension (%)	20.2	18.6
Systolic BP (mean ± SD)	120.7±19.8	119.6±19.8
Diastolic BP (mean ± SD)	75.4±13.2	74.8±13.1
Urban (%)	14.3	13.2

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Rajasthan:

Variable	Matched	Not matched
	n=81,931	*n=25,974*
Male (%)	49.6	44.6
Age (mean ± SD)	41.0±16.1	37.9±17.5
Diabetes (%)	6.9	6.2
Plasma glucose in mg/dl (mean ± SD)	109.7±20.4	109.0±19.7
Hypertension (%)	22.8	20.9
Systolic BP (mean ± SD)	122.9±18.5	121.9±18.3
Diastolic BP (mean ± SD)	78.7±11.9	78.2±11.8
Urban (%)	17.7	17.1

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Uttar Pradesh:

Variable	Matched	Not matched
	n=103,384	*n=148,213*
Male (%)	51.6	47.9
Age (mean ± SD)	40.4±16.3	39.4±17.2
Diabetes (%)	6.9	6.2
Plasma glucose in mg/dl (mean ± SD)	110.4±22.0	110.2±22.3
Hypertension (%)	21.8	22.0
Systolic BP (mean ± SD)	123.1±20.0	122.9±20.6
Diastolic BP (mean ± SD)	76.2±13.0	76.1±13.0
Urban (%)	21.3	17.5

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

Uttarakhand:

Variable	Matched	Not matched
	n=19,973	*n=19,958*
Male (%)	47.0	42.6
Age (mean ± SD)	42.7±16.6	40.1±17.3
Diabetes (%)	8.0	7.3
Plasma glucose in mg/dl (mean ± SD)	109.6±25.2	111.3±25.9
Hypertension (%)	32.1	25.9
Systolic BP (mean ± SD)	127.2±19.6	124.0±20.1
Diastolic BP (mean ± SD)	81.5±11.8	79.2±12.3
Urban (%)	22.0	21.3

Abbreviations: BP=blood pressure; SD=standard deviation; mg=milligram; dl= deciliter.

eMethods3. Computation of the household wealth index

While neither the AHS nor the DLHS-4 contained information on household income or expenditure, they both asked about household characteristics and ownership of durable assets, which allows for the creation of a household wealth index. We created a household wealth index through a Principal Component Analysis (PCA) using the methodology developed by Filmer and Pritchett.[58] The advantage of a PCA is that the weights attributed to each asset or housing characteristic (henceforth assets) are not determined arbitrarily by the authors but instead are data-driven.

As a first step, a binary indicator was generated for each asset. Data on the following assets were available in both surveys and coded as being equal to one if the household head reported owning or having access to the asset: improved water supply (private or public access to piped water, hand pump, tube well, borehole or protected dug well); improved sanitation facility (not shared (pour) flush toilet, Ventilated Improved Pit or pit latrine with slab), modern cooking fuel (liquefied petroleum gas, electricity, biogas), house structure (pucca), clean source of lighting (electricity, solar), house ownership, and land ownership. Furthermore, indicators for each of the following assets were set to one if the household head reported owning at least one item of the following durable goods: radio, television, phone, fridge, bike, scooter, car, computer, washing machine, and sewing machine.

As a second step, the PCA was run separately for urban and rural areas on these binary indicator variables and the first (unrotated) principal component was extracted. The first principal component contains the largest part of the information on the variation in asset ownership and was used to predict the asset score of each household. The asset score has a mean of zero and standard deviation of one with lower asset scores indicating less wealth. To improve interpretability, the asset score was divided into quintiles (again, separately for rural and urban areas).

Variables used to calculate the household wealth index:

Asset	**Coded as 1**	**Coded as 0**
Improved water supply	Piped water into dwelling, yard or plot; public tap or standpipe; hand pump; tube well or borehole; protected dug well	Tanker, truck or cart with small tank; surface water;
Improved sanitation facility	If not shared: (Pour) flush connected to piped sewer system, septic tank or pit latrine; Ventilated Improved Pit; pit latrine with slab	Any shared facility; pit latrine without slab; service latrine; open defecation
Cooking fuel	LPG; electricity; biogas	Firewood; crop residue; cow dung

		cake; coal, lignite or charcoal; kerosene
House structure	Pucca	Semi-Pucca, Kuccha
Source of lighting	Electricity; solar	Kerosene, other oils, none
Ownership of house land	Owned Ownership of any land	Rented No land owned
Radio TV Phone Fridge Bike Scooter Car Computer Washing machine Sewing machine	Household owns at least one of this asset	Household does not own this asset

eMethods4. Computation of sampling weights

The AHS is self-weighting at the district level. For AHS respondents, we therefore computed weights that consisted of the proportion that is obtained when dividing the relative population size of a district (i.e., population size of the district divided by the population size across all nine AHS states) by the relative sample size of a district (i.e., sample size of the district divided by total AHS sample size across all nine states). For DLHS-4 respondents the same weight was computed as above for the AHS, which was then multiplied by the weights given in the DLHS-4 dataset that adjust for the complex survey design (the DLHS-4 is not self-weighting). Lastly, the weights were adjusted for the fact that the AHS sample size is smaller relative to the population it represents than the DLHS-4 sample size. These weights were used to calculate all crude prevalence estimates provided in the manuscript.

To obtain age-standardized prevalence estimates, the weights for the crude prevalence estimates were multiplied by the proportion of adults in the respondent's five-year age group in the WHO reference population.[60] Code for the computation of these sampling weights can be obtained from the corresponding author.

eTable1. Sample characteristics stratified by whether the blood glucose or blood pressure measurement was missing[a]

	Not missing	Missing
n	1,320,555	297,804
Male, no. (%)	619,147 (46.9)	227,186 (76.3)
Age group, no. (%)		
18-25 years	253,154 (19.2)	76,191 (25.6)
26-35 years	320,018 (24.2)	70,311 (23.6)
36-45 years	281,706 (21.3)	56,158 (18.9)
46-55 years	212,465 (16.1)	42,385 (14.2)
56-65 years	150,940 (11.4)	30,635 (10.3)
>65 years	102,253 (7.7)	22,105 (7.4)
Education, no. (%)		
<Primary School	504,829 (38.4)	91,186 (30.8)
Primary School	163,953 (12.5)	34,474 (11.6)
Middle School	203,128 (15.4)	46,764 (15.8)
Secondary School	182,391 (13.9)	47,396 (16.0)
High School	128,270 (9.8)	36,654 (12.4)
>High School	132,544 (10.1)	39,459 (13.3)
Household wealth quintile, no. (%)		
1 (poorest)	254,652 (20.2)	51,072 (17.8)
2	248,101 (19.7)	55,014 (19.2)
3	245,748 (19.5)	57,270 (20.0)
4	253,905 (20.1)	60,619 (21.2)
5 (richest)	259,491 (20.6)	62,408 (21.8)
Currently married, no. (%)	988,456 (75.0)	198,873 (67.0)
Urban area, no. (%)	429,330 (32.5)	106,233 (35.7)

Abbreviations: no.=number; %=Percentage.

[a] These numbers were not weighted using sampling weights.

eTable2. National diabetes and hypertension prevalence by age group and sex[a,b]

	Diabetes		Hypertension	
	Female, % (95% CI)	*Male, % (95% CI)*	*Female, % (95% CI)*	*Male, % (95% CI)*
Age group				
18-25 years	2.6 (2.4 - 2.7)	2.4 (2.2 - 2.5)	9.2 (8.9 - 9.6)	14.6 (14.2 - 15.0)
26-35 years	4.0 (3.8 - 4.2)	4.6 (4.4 - 4.8)	14.2 (13.8 - 14.6)	21.0 (20.6 - 21.4)
36-45 years	7.0 (6.8 - 7.3)	7.5 (7.3 - 7.8)	23.0 (22.6 - 23.4)	27.7 (27.2 - 28.2)
46-55 years	11.2 (10.9 - 11.5)	11.3 (10.9 - 11.6)	32.7 (32.2 - 33.2)	33.7 (33.1 - 34.3)
56-65 years	13.2 (12.8 - 13.6)	13.5 (13.1 - 14.0)	41.2 (40.6 - 41.9)	39.0 (38.3 - 39.6)
>65 years	13.9 (13.4 - 14.4)	14.0 (13.5 - 14.5)	48.6 (47.9 - 49.3)	43.4 (42.7 - 44.2)
Total population				
Crude	7.3 (7.1 - 7.4)	7.8 (7.6 - 8.0)	23.6 (23.3 - 23.8)	27.4 (27.0 - 27.7)
Age-standardized[2]	6.1 (6.0 - 6.3)	6.5 (6.4 - 6.7)	20.0 (19.7 - 20.3)	24.5 (24.2 - 24.9)

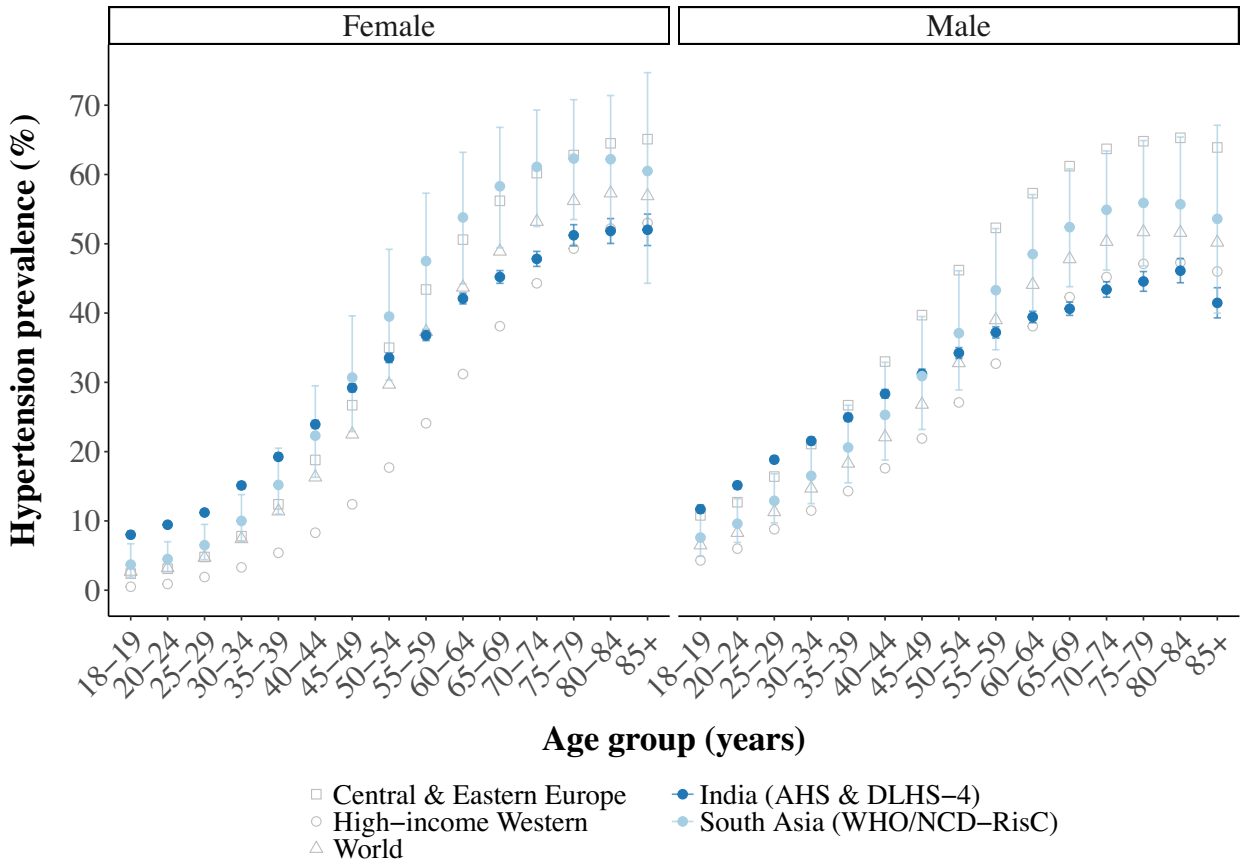
[a] The diabetes prevalence shown in this table assumes all AHS participants were fasted at the time of the blood glucose measurement. eTable3 shows national diabetes prevalence assuming all AHS participants were unfasted.
[b] Age-standardization was to the World Health Organization's reference population.[60]

eTable3. National diabetes prevalence assuming all AHS respondents were unfasted[a]

Age group	Diabetes	
	Female *Percent (95% CI)*	**Male** *Percent (95% CI)*
18-25 years	2.1 (2.0 - 2.3)	1.8 (1.7 - 1.9)
26-35 years	3.4 (3.2 - 3.5)	3.7 (3.5 - 3.8)
36-45 years	5.8 (5.5 – 6.0)	6.0 (5.8 - 6.2)
46-55 years	9.1 (8.8 - 9.5)	8.9 (8.6 - 9.2)
56-65 years	10.5 (10.2 - 10.9)	10.6 (10.2 - 10.9)
>65 years	10.6 (10.2 - 11.1)	10.3 (9.8 - 10.7)
Total (crude)	*5.9 (5.7 - 6.1)*	*6.1 (5.9 - 6.2)*
Total (age-standardized[1])	*5.0 (4.8 - 5.1)*	*5.1 (5.0 - 5.3)*

[a] Age-standardization was to the World Health Organization's reference population.[60]

eFigure2. Hypertension prevalence by five-year age group for India and WHO/NCD-RisC regions[a,b,c]



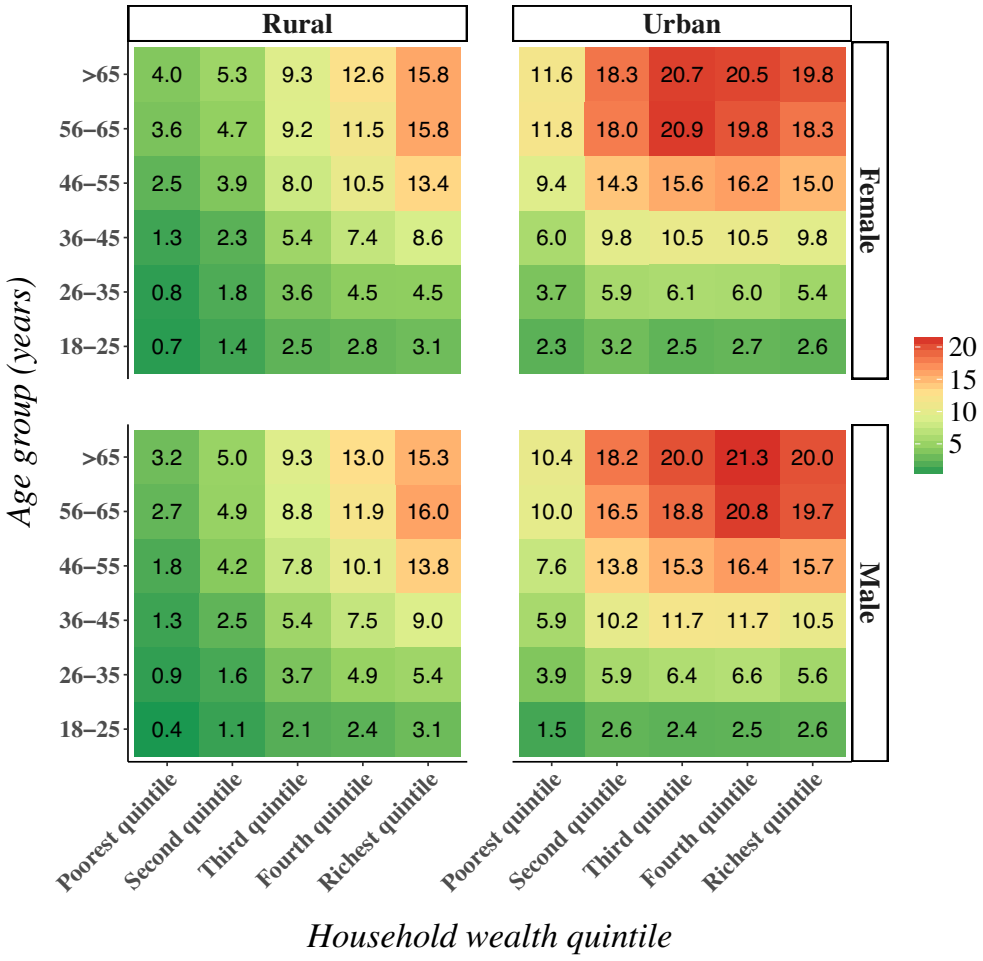
[a] Data for 'South Asia', 'Central & Eastern Europe', 'High-income Western', and 'World' were extracted from Zhou et al.[139]
[b] WHO/NCD-RisC estimates are for 2015.
[c] The countries included in each world region are listed below.

South Asia: Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan

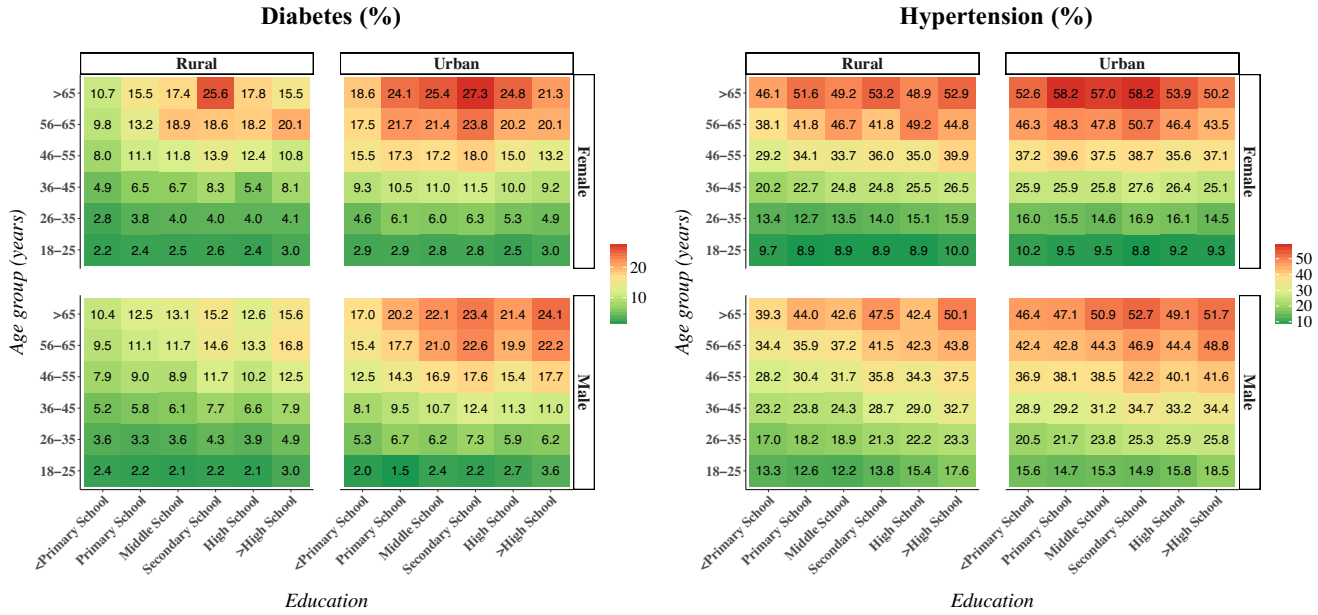
Central and Eastern Europe
Central Europe: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia (TFYR), Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia
Eastern Europe: Belarus, Estonia, Latvia, Lithuania, Moldova, Russian Federation, Ukraine

High-income Western countries
High-income English-speaking countries: Australia, Canada, Ireland, New Zealand, United Kingdom, United States of America
North-Western Europe: Austria, Belgium, Denmark, Finland, Germany, Greenland, Iceland, Luxembourg, Netherlands, Norway, Sweden, Switzerland
South-Western Europe: Andorra, Cyprus, France, Greece, Israel, Italy, Malta, Portugal, Spain

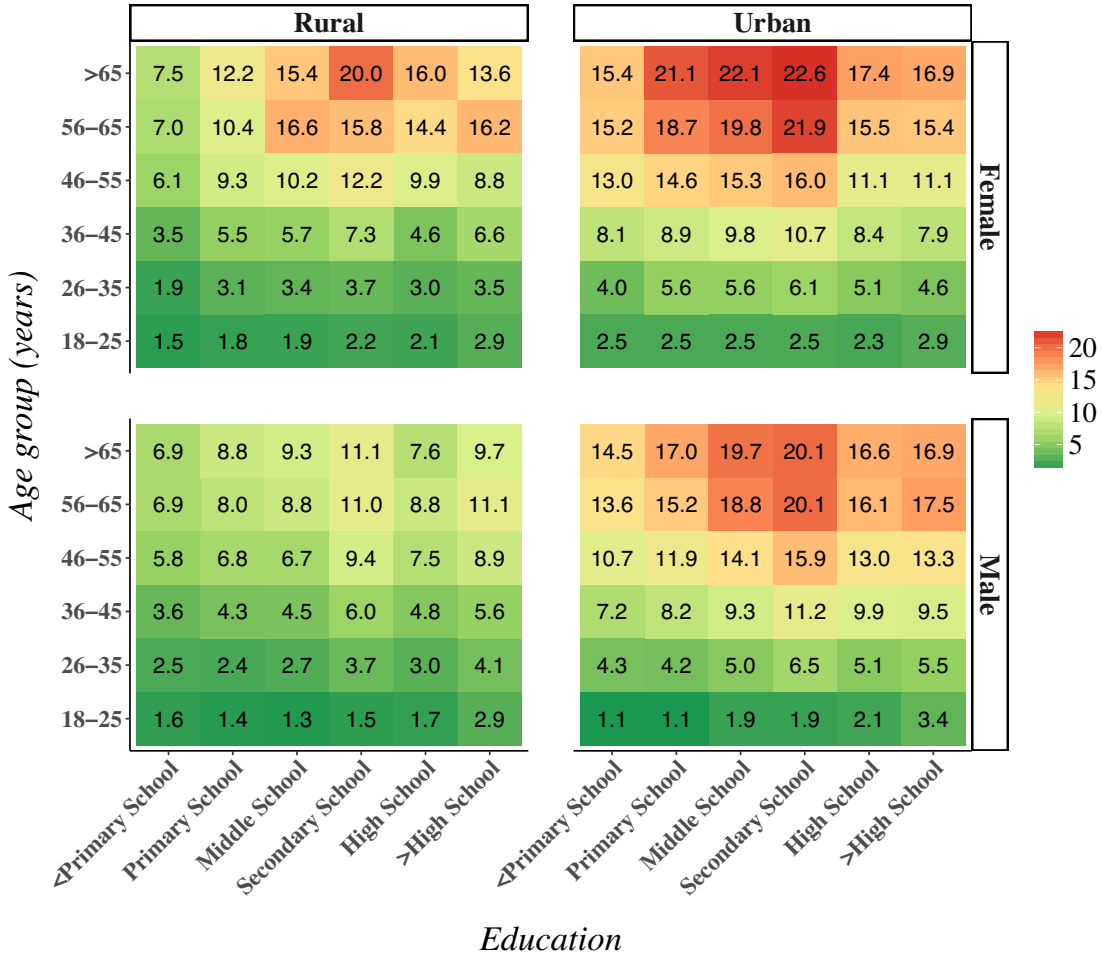
eFigure3. Prevalence of diabetes by rural versus urban residence, sex, and household wealth quintile assuming all AHS respondents were unfasted



eFigure4. Prevalence of diabetes and hypertension by rural versus urban residence, sex, and education



eFigure5. Prevalence of diabetes by rural versus urban residence, sex, and education assuming all AHS respondents were unfasted



eTable4. Regression results for diabetes assuming all AHS participants were unfasted[a,b]

Characteristic	Diabetes			
	Rural		Urban	
	Difference in probability[b] (95% CI)	*P*	*Difference in probability[b] (95% CI)*	*P*
Age group				
18-25 years	Ref.		Ref.	
26-35 years	1.28 (1.15 - 1.42)	<0.001	2.54 (2.30 - 2.77)	<0.001
36-45 years	3.14 (2.97 - 3.31)	<0.001	6.66 (6.34 - 6.98)	<0.001
46-55 years	5.35 (5.13 - 5.58)	<0.001	11.12 (10.71 - 11.53)	<0.001
56-65 years	6.81 (6.55 - 7.08)	<0.001	14.45 (13.95 - 14.95)	<0.001
>65 years	7.50 (7.19 - 7.81)	<0.001	15.17 (14.58 - 15.75)	<0.001
Wealth quintile				
1 (poorest)	Ref.		Ref.	
2	0.11 (-0.01 - 0.23)	<0.067	0.84 (0.54 - 1.14)	<0.001
3	0.24 (0.08 - 0.40)	<0.003	1.88 (1.53 - 2.22)	<0.001
4	0.72 (0.53 - 0.90)	<0.001	2.67 (2.29 - 3.04)	<0.001
5 (richest)	2.32 (2.08 - 2.56)	<0.001	3.32 (2.90 - 3.74)	<0.001
Education				
<Primary School	Ref.		Ref.	
Primary School	0.49 (0.34 - 0.65)	<0.001	0.67 (0.31 - 1.03)	<0.001
Middle School	0.37 (0.22 - 0.52)	<0.001	0.54 (0.21 - 0.87)	0.001
Secondary School	0.18 (0.00 - 0.37)	0.050	0.41 (0.08 - 0.75)	0.016
High School	-0.76 (-0.96 - -0.56)	0.001	-0.49 (-0.84 - -0.14)	0.006
>High School	-1.11 (-1.36 - -0.85)	0.001	-1.38 (-1.74 - -1.02)	<0.001
Currently married	-0.26 (-0.40 - -0.13)	<0.001	0.21 (-0.04 - 0.46)	0.197
Male	0.25 (0.16 - 0.35)	<0.001	0.56 (0.37 - 0.74)	<0.001

Abbreviations: Coeff.=Coefficient; CI=Confidence Interval; Ref.=Reference category.

[a] These linear probability models included all socio-demographic variables listed in the table (age group, wealth quintile, education, marital status, and sex) and a binary indicator for each PSU (PSU-level fixed effects). Standard errors were adjusted for clustering at the PSU level.

[b] These regressions coefficients should be interpreted as the average absolute difference (in percentage points) in the probability of having diabetes (compared to the reference category).

eTable5. Regression results for diabetes among those in whom fasting status could be ascertained (i.e., DLHS-4 participants only)[a,b]

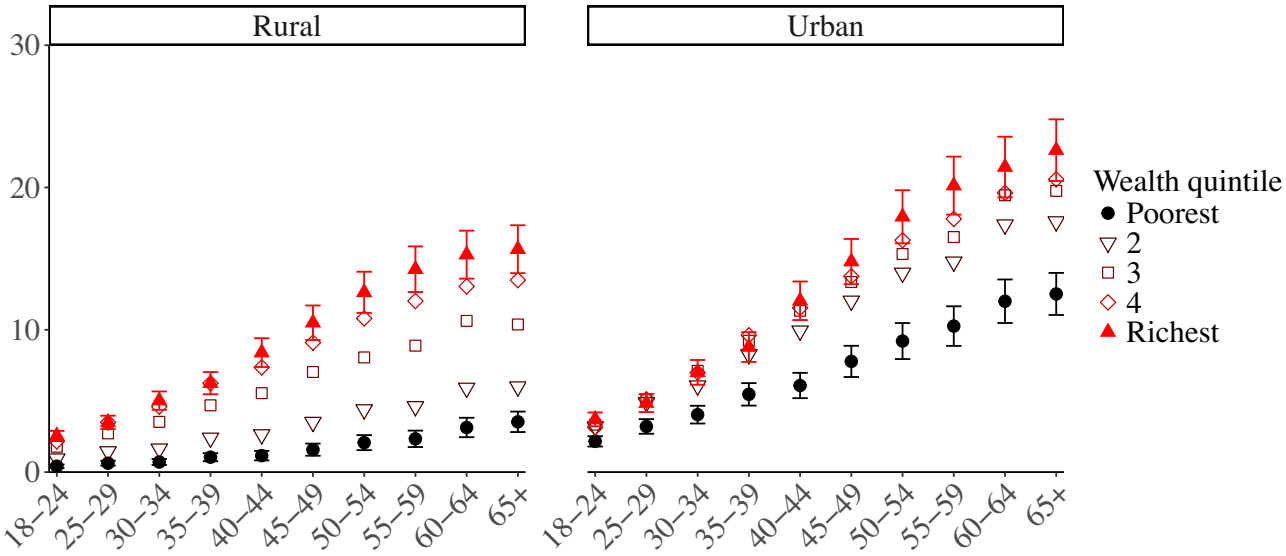
Characteristic	Diabetes			
	Rural		Urban	
	Difference in probability[b] (95% CI)	*P*	*Difference in probability[b] (95% CI)*	*P*
Age group				
18-25 years	Ref.		Ref.	
26-35 years	1.88 (1.69 - 2.06)	<0.001	3.19 (2.93 - 3.45)	<0.001
36-45 years	5.22 (4.96 - 5.48)	<0.001	8.53 (8.21 - 8.86)	<0.001
46-55 years	8.97 (8.62 - 9.31)	<0.001	14.13 (13.65 - 14.61)	<0.001
56-65 years	11.55 (11.16 - 11.94)	<0.001	18.32 (17.81 - 18.83)	<0.001
>65 years	13.08 (12.58 - 13.57)	<0.001	19.84 (19.00 - 20.68)	<0.001
Wealth quintile				
1 (poorest)	Ref.		Ref.	
2	0.76 (0.34 - 1.18)	<0.001	1.61 (1.19 - 2.04)	<0.001
3	1.46 (1.02 - 1.91)	<0.001	2.63 (2.16 - 3.09)	<0.001
4	2.68 (2.23 - 3.14)	<0.001	2.60 (2.13 - 3.06)	<0.001
5 (richest)	3.44 (2.93 - 3.96)	<0.001	1.74 (1.26 - 2.22)	<0.001
Education				
<Primary School	Ref.		Ref.	
Primary School	0.86 (0.57 - 1.16)	<0.001	1.06 (0.53 - 1.58)	<0.001
Middle School	0.86 (0.62 - 1.10)	<0.001	1.13 (0.68 - 1.58)	<0.001
Secondary School	1.17 (0.86 - 1.49)	<0.001	1.35 (0.88 - 1.83)	<0.001
High School	0.06 (-0.24 - 0.36)	0.694	0.22 (-0.33 - 0.77)	0.430
>High School	1.04 (0.71 - 1.36)	<0.001	0.50 (-0.10 - 1.10)	0.102
Currently married	0.32 (0.11 - 0.53)	0.003	0.64 (0.32 - 0.96)	<0.001
Male	-0.06 (-0.22 - 0.10)	0.435	0.12 (-0.06 - 0.30)	0.183

Abbreviations: Coeff.=Coefficient; CI=Confidence Interval; Ref.=Reference category.

[a] These linear probability models included all socio-demographic variables listed in the table (age group, wealth quintile, education, marital status, and sex) and a binary indicator for each PSU (PSU-level fixed effects). Standard errors were adjusted for clustering at the PSU level.

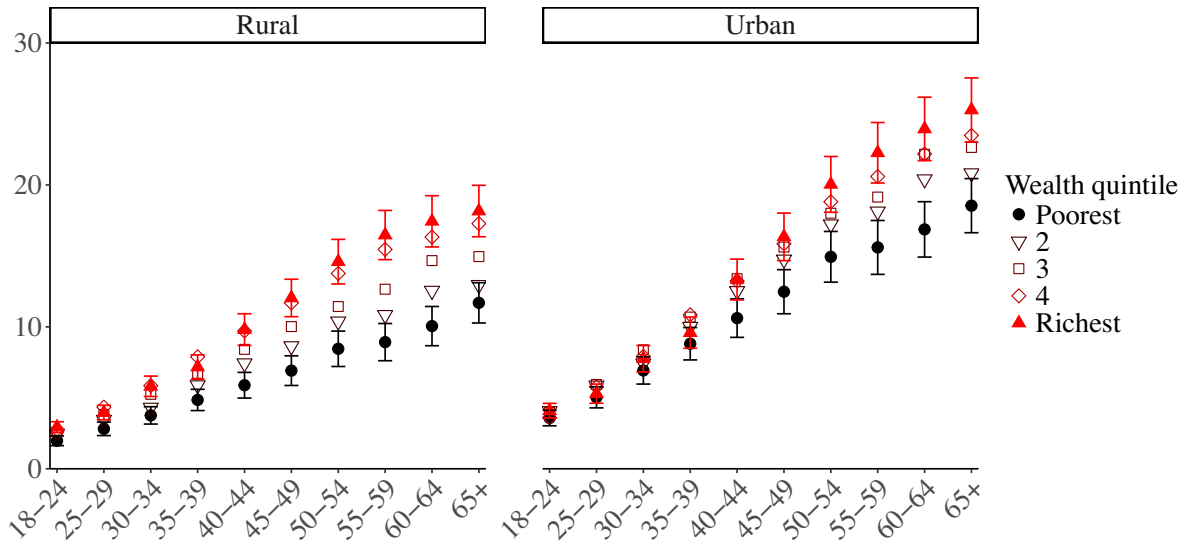
[b] These regressions coefficients should be interpreted as the average absolute difference (in percentage points) in the probability of having diabetes (compared to the reference category).

eFigure6. The predicted probability of diabetes by age group, rural-urban location, and household wealth quintile assuming AHS participants were unfasted[a]



[a] Predicted probabilities were obtained from multivariable logistic regressions of diabetes on individuals' socio-demographic characteristics (age group, household wealth quintile, education, marital status, sex, and rural-urban location), district-level fixed effects (i.e., a binary indicator for each district), and an interaction term between age group and household wealth quintile.

eFigure7. The predicted probability of diabetes by age group, rural-urban location, and household wealth quintile among those in whom fasting status could be ascertained (i.e., DLHS-4 participants only)[a]



[a] Predicted probabilities were obtained from multivariable logistic regressions of diabetes on individuals' socio-demographic characteristics (age group, household wealth quintile, education, marital status, sex, and rural-urban location), district-level fixed effects (i.e., a binary indicator for each district), and an interaction term between age group and household wealth quintile.

eTable6. State-level age-standardized diabetes and hypertension prevalence estimates by sex

State	Sex	Diabetes			Hypertension		
		Estimate	Lower 95% CI	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI
Andaman and Nicobar	Female	7.96	6.49	9.72	26.34	23.35	29.57
Andaman and Nicobar	Male	8.57	6.69	10.92	37.16	34.18	40.25
Andhra Pradesh	Female	8.90	8.36	9.48	20.69	20.01	21.40
Andhra Pradesh	Male	9.43	8.86	10.03	28.26	27.34	29.20
Arunachal Pradesh	Female	4.50	3.47	5.81	21.42	19.84	23.10
Arunachal Pradesh	Male	4.33	3.33	5.61	27.69	26.39	29.04
Assam	Female	3.36	2.93	3.85	16.82	15.17	18.62
Assam	Male	3.92	3.38	4.55	21.26	19.47	23.16
Bihar	Female	2.39	2.02	2.82	20.82	19.37	22.34
Bihar	Male	3.06	2.64	3.53	20.24	19.00	21.53
Chandigarh	Female	9.75	7.79	12.14	31.30	28.14	34.65
Chandigarh	Male	10.56	8.75	12.69	41.75	38.21	45.37
Chhattisgarh	Female	3.62	3.08	4.25	13.50	12.19	14.93
Chhattisgarh	Male	5.30	4.49	6.24	17.12	15.69	18.64
Daman and Diu	Female	9.71	7.22	12.95	36.28	31.77	41.04
Daman and Diu	Male	6.72	4.32	10.32	43.53	38.33	48.87
Goa	Female	16.37	14.20	18.79	26.37	22.99	30.04
Goa	Male	17.90	15.37	20.74	32.90	29.09	36.95
Haryana	Female	5.52	5.20	5.85	20.33	19.74	20.93
Haryana	Male	5.53	5.20	5.87	28.10	27.38	28.82
Himachal Pradesh	Female	3.31	2.91	3.76	30.79	29.60	32.00
Himachal Pradesh	Male	3.26	2.83	3.76	38.53	37.07	40.02
Jharkhand	Female	3.08	2.59	3.66	18.81	17.48	20.23
Jharkhand	Male	3.85	3.28	4.52	24.72	22.80	26.75
Karnataka	Female	9.38	8.99	9.77	21.01	20.60	21.42
Karnataka	Male	10.17	9.74	10.61	25.45	24.89	26.02
Kerala	Female	11.76	10.79	12.82	32.98	31.28	34.72
Kerala	Male	14.43	13.15	15.81	41.35	39.25	43.47
Madhya Pradesh	Female	2.33	1.98	2.75	16.67	15.65	17.74
Madhya Pradesh	Male	2.75	2.25	3.34	19.87	18.64	21.15
Maharashtra	Female	5.13	4.83	5.44	21.76	21.18	22.35
Maharashtra	Male	5.58	5.26	5.93	28.17	27.42	28.92
Manipur	Female	7.39	6.72	8.14	17.59	16.52	18.72
Manipur	Male	7.94	7.23	8.70	25.69	24.27	27.16

Meghalaya	Female	2.87	2.28	3.60	18.27	16.77	19.89
Meghalaya	Male	2.97	2.33	3.77	22.91	20.91	25.03
Mizoram	Female	3.45	3.01	3.95	14.82	13.97	15.72
Mizoram	Male	3.59	3.17	4.07	24.54	23.33	25.78
Nagaland	Female	5.58	5.03	6.18	31.78	30.15	33.44
Nagaland	Male	6.43	5.80	7.13	39.59	37.84	41.37
NCT of Delhi	Female	9.41	8.69	10.18	22.41	20.96	23.94
NCT of Delhi	Male	9.47	8.78	10.21	27.94	26.36	29.59
Odisha	Female	2.87	2.63	3.13	15.56	14.47	16.72
Odisha	Male	3.65	3.35	3.97	17.24	15.93	18.63
Puducherry	Female	15.50	14.38	16.68	17.62	16.58	18.71
Puducherry	Male	16.33	14.96	17.80	27.33	25.66	29.06
Punjab	Female	7.23	6.89	7.59	29.43	28.82	30.04
Punjab	Male	6.79	6.44	7.16	41.38	40.61	42.16
Rajasthan	Female	2.76	2.41	3.16	16.47	15.42	17.58
Rajasthan	Male	3.04	2.67	3.47	23.68	22.11	25.33
Sikkim	Female	5.21	4.42	6.14	30.44	28.71	32.23
Sikkim	Male	4.99	4.29	5.79	36.18	34.09	38.32
Tamil Nadu	Female	14.89	14.44	15.36	18.84	18.44	19.24
Tamil Nadu	Male	15.88	15.40	16.38	27.69	27.13	28.25
Telangana	Female	7.57	6.86	8.35	19.62	18.68	20.59
Telangana	Male	8.47	7.66	9.35	26.52	25.36	27.72
Tripura	Female	8.99	7.81	10.33	18.81	17.18	20.56
Tripura	Male	9.89	8.62	11.33	22.41	20.41	24.55
Uttar Pradesh	Female	3.16	2.84	3.52	18.17	17.11	19.28
Uttar Pradesh	Male	3.41	3.01	3.86	20.53	19.14	21.98
Uttarakhand	Female	3.86	2.78	5.34	22.28	19.92	24.83
Uttarakhand	Male	4.07	3.26	5.07	32.24	29.44	35.17
West Bengal	Female	9.33	8.74	9.96	21.03	20.29	21.78
West Bengal	Male	9.98	9.36	10.64	22.62	21.77	23.49

Abbreviation: CI=Confidence interval.

eTable7. State-level age-standardized diabetes and hypertension prevalence estimates by rural versus urban location

State	Rural or urban	Diabetes			Hypertension		
		Estimate	Lower 95% CI	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI
Andaman and Nicobar	Rural	8.45	6.46	10.99	33.21	30.15	36.42
Andaman and Nicobar	Urban	7.88	5.86	10.51	28.17	23.53	33.32
Andhra Pradesh	Rural	7.97	7.40	8.58	23.04	22.26	23.85
Andhra Pradesh	Urban	12.12	11.29	13.01	26.86	25.70	28.05
Arunachal Pradesh	Rural	3.28	2.85	3.78	24.76	23.66	25.89
Arunachal Pradesh	Urban	6.43	4.38	9.34	23.61	20.91	26.55
Assam	Rural	3.42	2.94	3.96	18.31	16.83	19.89
Assam	Urban	4.86	3.56	6.59	22.47	19.01	26.35
Bihar	Rural	2.50	2.13	2.94	20.17	18.90	21.50
Bihar	Urban	4.16	3.05	5.65	23.99	21.26	26.96
Chandigarh	Rural	11.08	7.08	16.94	37.09	34.20	40.07
Chandigarh	Urban	9.86	8.14	11.91	36.30	32.80	39.95
Chhattisgarh	Rural	3.74	3.16	4.43	14.66	13.21	16.24
Chhattisgarh	Urban	6.87	5.32	8.84	17.72	15.39	20.31
Daman and Diu	Rural	9.40	6.73	12.97	36.04	32.24	40.02
Daman and Diu	Urban	2.25	1.17	4.29	62.71	54.71	70.07
Goa	Rural	17.39	15.11	19.93	31.68	28.56	34.98
Goa	Urban	16.83	13.81	20.35	27.76	22.81	33.33
Haryana	Rural	5.21	4.86	5.58	22.66	21.97	23.36
Haryana	Urban	6.08	5.63	6.56	26.32	25.40	27.27
Himachal Pradesh	Rural	3.28	2.91	3.70	33.75	32.68	34.84
Himachal Pradesh	Urban	3.35	2.49	4.50	35.52	31.06	40.25
Jharkhand	Rural	2.80	2.30	3.40	19.95	18.22	21.80
Jharkhand	Urban	5.55	4.56	6.74	26.18	24.50	27.93
Karnataka	Rural	8.46	8.03	8.92	20.73	20.27	21.19
Karnataka	Urban	11.68	11.08	12.31	26.46	25.83	27.09
Kerala	Rural	11.81	10.28	13.52	38.81	36.11	41.58
Kerala	Urban	14.21	12.86	15.69	34.04	31.77	36.39
Madhya Pradesh	Rural	2.02	1.70	2.41	17.39	16.30	18.54
Madhya Pradesh	Urban	3.54	2.62	4.77	20.19	18.16	22.39
Maharashtra	Rural	4.68	4.33	5.07	23.51	22.75	24.28
Maharashtra	Urban	6.17	5.73	6.64	26.14	25.20	27.11
Manipur	Rural	7.45	6.74	8.23	20.42	19.15	21.74
Manipur	Urban	8.01	6.94	9.23	22.99	20.94	25.18

Meghalaya	Rural	2.75	2.14	3.52	19.25	17.56	21.08
Meghalaya	Urban	3.48	2.29	5.24	22.87	19.75	26.32
Mizoram	Rural	3.01	2.54	3.58	18.21	17.00	19.47
Mizoram	Urban	3.94	3.39	4.56	20.63	19.44	21.88
Nagaland	Rural	5.86	5.25	6.54	35.90	34.14	37.70
Nagaland	Urban	6.29	5.37	7.36	34.78	31.78	37.91
NCT of Delhi	Rural	9.86	8.51	11.40	23.62	20.34	27.26
NCT of Delhi	Urban	9.35	8.67	10.07	25.64	24.08	27.28
Odisha	Rural	2.94	2.71	3.18	15.70	14.46	17.02
Odisha	Urban	4.98	4.26	5.81	20.16	17.67	22.91
Puducherry	Rural	15.81	13.62	18.27	18.45	16.40	20.69
Puducherry	Urban	15.87	14.70	17.12	23.09	22.01	24.21
Punjab	Rural	6.75	6.36	7.17	35.46	34.71	36.23
Punjab	Urban	7.49	7.00	8.01	34.38	33.44	35.34
Rajasthan	Rural	2.43	2.09	2.83	18.32	17.31	19.37
Rajasthan	Urban	4.78	3.96	5.76	26.05	22.34	30.13
Sikkim	Rural	5.12	4.37	5.99	32.26	30.52	34.05
Sikkim	Urban	5.07	3.96	6.48	35.44	31.98	39.06
Tamil Nadu	Rural	13.28	12.75	13.83	21.26	20.74	21.78
Tamil Nadu	Urban	17.50	16.91	18.10	24.28	23.71	24.85
Telangana	Rural	7.41	6.47	8.48	21.43	20.28	22.61
Telangana	Urban	9.01	8.09	10.01	25.50	24.01	27.04
Tripura	Rural	9.20	7.90	10.68	18.35	16.64	20.19
Tripura	Urban	10.00	7.83	12.70	26.33	23.02	29.93
Uttar Pradesh	Rural	2.85	2.48	3.28	18.93	17.56	20.37
Uttar Pradesh	Urban	4.59	3.98	5.30	20.34	18.44	22.40
Uttarakhand	Rural	3.06	2.14	4.37	25.11	21.83	28.70
Uttarakhand	Urban	6.13	4.50	8.28	30.34	27.68	33.13
West Bengal	Rural	8.97	8.28	9.71	19.79	18.92	20.68
West Bengal	Urban	11.16	10.46	11.90	26.37	25.45	27.31

Abbreviation: CI=Confidence interval.

eTable8. State-level crude diabetes and hypertension prevalence estimates by age group

State	Age (years)	Diabetes			Hypertension		
		Estimate	Lower 95% CI	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI
Andaman and Nicobar	18-25	3.72	2.27	6.03	16.36	12.67	20.88
Andaman and Nicobar	26-35	5.87	4.15	8.23	25.19	22.16	28.48
Andaman and Nicobar	36-45	10.58	8.11	13.69	36.40	32.03	41.00
Andaman and Nicobar	46-55	11.80	9.60	14.42	44.79	39.85	49.83
Andaman and Nicobar	56-65	14.75	11.26	19.08	52.56	47.60	57.46
Andaman and Nicobar	>65	19.13	14.24	25.21	65.62	58.86	71.80
Andhra Pradesh	18-25	2.80	2.37	3.32	10.43	9.71	11.20
Andhra Pradesh	26-35	5.84	5.28	6.46	18.43	17.47	19.42
Andhra Pradesh	36-45	11.81	10.95	12.72	27.73	26.59	28.89
Andhra Pradesh	46-55	16.01	14.89	17.19	38.40	36.98	39.85
Andhra Pradesh	56-65	19.55	18.25	20.92	47.28	45.65	48.91
Andhra Pradesh	>65	20.20	18.61	21.90	52.70	50.59	54.79
Arunachal Pradesh	18-25	1.82	1.13	2.93	14.90	13.56	16.36
Arunachal Pradesh	26-35	4.30	3.21	5.75	21.01	19.37	22.74
Arunachal Pradesh	36-45	4.76	3.81	5.94	29.07	26.71	31.56
Arunachal Pradesh	46-55	7.26	5.63	9.32	38.95	35.63	42.38
Arunachal Pradesh	56-65	10.82	5.94	18.91	40.96	37.59	44.41
Arunachal Pradesh	>65	8.83	5.39	14.13	43.78	39.98	47.65
Assam	18-25	1.05	0.70	1.57	7.63	6.70	8.67
Assam	26-35	1.98	1.55	2.52	13.00	10.73	15.67
Assam	36-45	4.31	3.58	5.19	20.95	19.32	22.68
Assam	46-55	6.45	5.44	7.63	33.18	29.48	37.10
Assam	56-65	9.18	7.85	10.70	39.04	35.45	42.75
Assam	>65	12.54	10.99	14.28	49.18	46.40	51.97
Bihar	18-25	1.14	0.89	1.45	11.27	9.95	12.75
Bihar	26-35	1.44	1.15	1.79	16.75	15.40	18.19
Bihar	36-45	2.98	2.43	3.64	24.38	22.56	26.30
Bihar	46-55	4.63	3.85	5.55	27.56	25.75	29.44
Bihar	56-65	6.58	5.50	7.86	33.67	31.55	35.86
Bihar	>65	7.06	5.87	8.48	39.01	36.72	41.35
Chandigarh	18-25	4.14	2.58	6.58	20.29	17.11	23.89
Chandigarh	26-35	6.09	3.92	9.35	31.52	27.70	35.60
Chandigarh	36-45	13.32	10.67	16.51	44.52	40.17	48.97
Chandigarh	46-55	17.76	14.38	21.72	52.03	47.20	56.83
Chandigarh	56-65	21.72	16.78	27.63	57.18	50.32	63.78

Chandigarh	>65	21.91	15.28	30.40	61.94	51.86	71.09
Chhattisgarh	18-25	2.07	1.60	2.68	7.77	6.67	9.03
Chhattisgarh	26-35	2.84	2.27	3.53	10.34	9.28	11.52
Chhattisgarh	36-45	4.90	4.02	5.95	17.65	15.99	19.44
Chhattisgarh	46-55	7.81	6.48	9.37	24.83	22.42	27.41
Chhattisgarh	56-65	11.53	9.43	14.03	33.10	29.80	36.57
Chhattisgarh	>65	10.95	8.96	13.33	38.20	35.10	41.40
Daman and Diu	18-25	3.79	2.30	6.16	30.46	25.19	36.30
Daman and Diu	26-35	7.33	3.64	14.23	33.10	28.49	38.06
Daman and Diu	36-45	10.63	7.14	15.53	45.11	39.12	51.24
Daman and Diu	46-55	16.59	11.39	23.53	51.61	44.41	58.74
Daman and Diu	56-65	18.18	11.80	26.98	64.50	56.47	71.78
Daman and Diu	>65	17.26	9.49	29.35	57.15	47.62	66.17
Goa	18-25	8.17	5.60	11.78	15.31	11.29	20.43
Goa	26-35	12.77	10.35	15.65	22.68	18.75	27.16
Goa	36-45	17.38	14.19	21.10	32.08	27.12	37.47
Goa	46-55	25.10	21.31	29.30	40.33	36.01	44.81
Goa	56-65	26.21	22.35	30.48	45.74	40.96	50.59
Goa	>65	41.02	35.72	46.53	51.06	45.42	56.66
Haryana	18-25	2.84	2.55	3.16	15.49	14.75	16.25
Haryana	26-35	4.40	4.02	4.80	20.43	19.67	21.20
Haryana	36-45	6.37	5.92	6.86	27.97	27.08	28.88
Haryana	46-55	9.32	8.67	10.01	34.50	33.44	35.58
Haryana	56-65	11.15	10.41	11.93	40.44	39.23	41.67
Haryana	>65	11.78	10.83	12.79	47.68	46.22	49.15
Himachal Pradesh	18-25	0.90	0.58	1.41	23.13	21.33	25.04
Himachal Pradesh	26-35	1.74	1.32	2.28	27.59	26.04	29.19
Himachal Pradesh	36-45	3.11	2.57	3.76	35.65	33.91	37.44
Himachal Pradesh	46-55	5.71	4.87	6.67	42.40	40.41	44.41
Himachal Pradesh	56-65	6.85	5.87	7.99	49.15	46.64	51.67
Himachal Pradesh	>65	8.45	7.10	10.04	52.81	49.92	55.68
Jharkhand	18-25	0.55	0.33	0.90	10.82	9.27	12.58
Jharkhand	26-35	1.63	1.21	2.19	15.33	13.72	17.09
Jharkhand	36-45	4.14	3.43	4.99	24.34	22.62	26.15
Jharkhand	46-55	7.47	6.33	8.80	34.43	32.20	36.73
Jharkhand	56-65	9.82	8.09	11.86	43.79	40.98	46.63
Jharkhand	>65	9.82	8.15	11.80	49.53	46.59	52.49
Karnataka	18-25	4.09	3.76	4.44	9.61	9.17	10.07
Karnataka	26-35	6.50	6.12	6.90	16.94	16.39	17.51

Karnataka	36-45	11.93	11.36	12.53	27.87	27.18	28.58
Karnataka	46-55	17.12	16.35	17.92	38.15	37.26	39.05
Karnataka	56-65	19.76	18.83	20.73	46.10	45.05	47.15
Karnataka	>65	21.40	20.32	22.52	52.63	51.44	53.83
Kerala	18-25	5.71	4.55	7.14	21.79	19.48	24.29
Kerala	26-35	8.83	7.53	10.33	30.68	28.17	33.31
Kerala	36-45	12.95	11.69	14.33	39.18	36.56	41.87
Kerala	46-55	18.73	17.36	20.19	46.27	44.21	48.34
Kerala	56-65	24.51	22.82	26.28	51.87	50.11	53.62
Kerala	>65	24.51	22.77	26.34	57.68	55.84	59.49
Madhya Pradesh	18-25	0.92	0.69	1.22	11.01	9.74	12.42
Madhya Pradesh	26-35	1.68	1.10	2.55	14.79	13.51	16.17
Madhya Pradesh	36-45	2.67	2.31	3.08	19.54	18.30	20.84
Madhya Pradesh	46-55	4.79	3.73	6.14	27.78	26.07	29.56
Madhya Pradesh	56-65	6.59	5.59	7.76	35.28	33.44	37.17
Madhya Pradesh	>65	7.87	6.76	9.16	40.99	38.68	43.35
Maharashtra	18-25	2.20	1.96	2.47	15.14	14.36	15.96
Maharashtra	26-35	3.84	3.52	4.18	20.29	19.56	21.05
Maharashtra	36-45	5.84	5.43	6.27	27.61	26.81	28.43
Maharashtra	46-55	9.13	8.55	9.74	34.86	33.90	35.83
Maharashtra	56-65	11.32	10.65	12.03	40.40	39.41	41.41
Maharashtra	>65	11.49	10.73	12.31	45.08	43.94	46.22
Manipur	18-25	2.92	2.32	3.67	10.40	9.21	11.73
Manipur	26-35	5.10	4.43	5.87	14.88	13.77	16.05
Manipur	36-45	8.61	7.64	9.69	24.98	23.12	26.93
Manipur	46-55	11.93	10.61	13.38	33.08	30.77	35.47
Manipur	56-65	15.95	14.32	17.73	36.81	34.34	39.35
Manipur	>65	20.04	17.91	22.37	42.52	39.55	45.56
Meghalaya	18-25	1.65	1.15	2.35	12.91	11.36	14.64
Meghalaya	26-35	1.86	1.32	2.61	16.21	14.50	18.08
Meghalaya	36-45	3.01	2.22	4.07	24.12	21.49	26.96
Meghalaya	46-55	6.68	5.24	8.49	31.28	28.67	34.01
Meghalaya	56-65	6.82	5.22	8.87	38.30	34.00	42.79
Meghalaya	>65	7.49	5.27	10.55	49.94	44.70	55.18
Mizoram	18-25	1.41	1.07	1.85	12.68	11.51	13.95
Mizoram	26-35	2.39	1.98	2.87	17.94	16.74	19.21
Mizoram	36-45	4.24	3.52	5.11	21.32	19.83	22.88
Mizoram	46-55	6.32	5.38	7.41	27.15	25.37	29.01
Mizoram	56-65	7.33	6.08	8.80	30.37	28.05	32.79

Mizoram	>65	12.51	10.58	14.74	38.19	35.55	40.90
Nagaland	18-25	2.78	2.15	3.59	16.04	14.39	17.83
Nagaland	26-35	4.33	3.63	5.16	26.54	24.74	28.41
Nagaland	36-45	6.63	5.79	7.59	39.93	37.78	42.12
Nagaland	46-55	8.37	7.37	9.48	48.43	46.24	50.63
Nagaland	56-65	9.63	8.40	11.02	56.45	53.98	58.89
Nagaland	>65	11.48	9.99	13.16	62.25	59.73	64.71
NCT of Delhi	18-25	3.81	3.26	4.45	17.15	15.36	19.11
NCT of Delhi	26-35	7.33	6.54	8.21	22.35	20.66	24.12
NCT of Delhi	36-45	13.23	12.06	14.50	29.59	27.76	31.48
NCT of Delhi	46-55	16.32	14.86	17.89	35.87	33.76	38.04
NCT of Delhi	56-65	19.44	17.40	21.67	42.00	39.49	44.56
NCT of Delhi	>65	23.70	20.26	27.52	47.32	43.37	51.31
Odisha	18-25	0.54	0.39	0.76	6.51	5.60	7.55
Odisha	26-35	1.36	1.16	1.61	10.46	9.34	11.69
Odisha	36-45	3.25	2.91	3.63	17.16	15.74	18.67
Odisha	46-55	6.70	6.04	7.42	25.67	23.94	27.49
Odisha	56-65	8.40	7.58	9.30	34.47	32.63	36.36
Odisha	>65	8.83	8.00	9.73	42.25	40.44	44.09
Puducherry	18-25	4.17	3.33	5.20	8.38	7.11	9.86
Puducherry	26-35	10.98	9.66	12.45	13.41	11.98	14.98
Puducherry	36-45	19.03	17.25	20.94	24.94	23.06	26.92
Puducherry	46-55	25.62	23.49	27.86	33.26	31.28	35.31
Puducherry	56-65	32.05	29.35	34.88	45.76	43.05	48.50
Puducherry	>65	32.87	29.65	36.25	53.32	49.78	56.82
Punjab	18-25	2.62	2.36	2.90	19.80	19.04	20.57
Punjab	26-35	4.73	4.36	5.13	29.13	28.32	29.96
Punjab	36-45	8.18	7.68	8.71	42.00	41.06	42.95
Punjab	46-55	13.01	12.30	13.75	52.64	51.61	53.66
Punjab	56-65	16.40	15.55	17.29	59.68	58.57	60.77
Punjab	>65	17.80	16.73	18.93	64.64	63.34	65.91
Rajasthan	18-25	1.19	0.93	1.53	10.15	9.02	11.39
Rajasthan	26-35	1.66	1.33	2.07	14.83	13.78	15.94
Rajasthan	36-45	3.09	2.63	3.63	21.96	20.36	23.64
Rajasthan	46-55	5.17	4.51	5.92	30.52	28.78	32.33
Rajasthan	56-65	7.36	6.41	8.42	40.32	37.90	42.80
Rajasthan	>65	8.55	7.45	9.80	47.25	44.91	49.60
Sikkim	18-25	2.62	1.87	3.65	17.13	15.17	19.28
Sikkim	26-35	3.10	2.47	3.89	29.13	26.70	31.69

Sikkim	36-45	6.43	5.20	7.94	39.39	36.73	42.12
Sikkim	46-55	9.11	7.51	11.01	54.28	50.54	57.98
Sikkim	56-65	12.76	10.52	15.40	52.34	48.15	56.50
Sikkim	>65	10.83	8.44	13.79	56.32	52.01	60.54
Tamil Nadu	18-25	5.20	4.78	5.65	9.58	9.09	10.10
Tamil Nadu	26-35	10.59	10.09	11.12	16.53	15.97	17.10
Tamil Nadu	36-45	18.14	17.49	18.79	25.19	24.53	25.88
Tamil Nadu	46-55	25.41	24.59	26.25	35.22	34.40	36.05
Tamil Nadu	56-65	29.48	28.50	30.48	43.89	42.89	44.89
Tamil Nadu	>65	29.60	28.43	30.80	49.64	48.40	50.87
Telangana	18-25	3.83	2.97	4.92	12.87	11.67	14.17
Telangana	26-35	5.91	5.12	6.80	19.31	18.22	20.45
Telangana	36-45	9.64	8.69	10.67	28.15	26.62	29.72
Telangana	46-55	14.39	13.02	15.88	33.76	31.88	35.70
Telangana	56-65	15.22	13.76	16.80	39.58	37.50	41.71
Telangana	>65	17.55	15.56	19.73	44.65	41.60	47.74
Tripura	18-25	4.24	3.27	5.48	11.57	9.89	13.49
Tripura	26-35	6.69	5.42	8.25	17.42	15.43	19.62
Tripura	36-45	11.52	9.71	13.60	23.38	21.09	25.84
Tripura	46-55	16.46	14.15	19.07	30.23	27.24	33.40
Tripura	56-65	19.27	16.46	22.43	36.11	31.94	40.50
Tripura	>65	24.51	20.70	28.77	46.95	43.11	50.83
Uttar Pradesh	18-25	1.21	0.94	1.56	11.88	10.63	13.25
Uttar Pradesh	26-35	1.91	1.60	2.27	15.11	13.79	16.53
Uttar Pradesh	36-45	3.55	3.09	4.07	22.20	20.79	23.69
Uttar Pradesh	46-55	6.73	5.97	7.58	27.53	25.91	29.21
Uttar Pradesh	56-65	7.26	6.43	8.20	32.38	30.50	34.32
Uttar Pradesh	>65	7.84	6.97	8.81	37.63	35.57	39.73
Uttarakhand	18-25	1.11	0.44	2.78	13.01	10.42	16.14
Uttarakhand	26-35	1.47	0.84	2.56	20.60	17.84	23.67
Uttarakhand	36-45	4.72	3.51	6.30	29.24	26.30	32.36
Uttarakhand	46-55	6.43	4.93	8.35	40.29	36.21	44.51
Uttarakhand	56-65	12.19	9.76	15.13	48.48	43.98	53.01
Uttarakhand	>65	10.91	8.37	14.10	54.20	49.81	58.52
West Bengal	18-25	4.70	4.17	5.29	9.58	8.87	10.33
West Bengal	26-35	7.58	6.92	8.30	16.24	15.34	17.17
West Bengal	36-45	11.11	10.35	11.91	25.54	24.43	26.68
West Bengal	46-55	15.47	14.36	16.65	34.76	33.45	36.10
West Bengal	56-65	17.06	15.87	18.31	42.98	41.35	44.62

West Bengal	>65	20.26	18.72	21.88	51.22	49.23	53.20

eTable9. State-level age-standardized diabetes prevalence estimates by sex assuming all AHS respondents were unfasted

State	Sex	Diabetes		
		Estimate	Lower 95% CI	Upper 95% CI
Assam	Female	0.47	0.35	0.63
Assam	Male	0.50	0.36	0.68
Bihar	Female	0.25	0.19	0.34
Bihar	Male	0.38	0.28	0.50
Chhattisgarh	Female	0.21	0.14	0.31
Chhattisgarh	Male	0.47	0.33	0.65
Jharkhand	Female	0.82	0.62	1.07
Jharkhand	Male	1.16	0.90	1.50
Madhya Pradesh	Female	0.34	0.28	0.42
Madhya Pradesh	Male	0.47	0.36	0.63
Odisha	Female	0.70	0.61	0.80
Odisha	Male	0.87	0.74	1.01
Rajasthan	Female	0.40	0.33	0.48
Rajasthan	Male	0.37	0.30	0.45
Uttar Pradesh	Female	0.69	0.59	0.80
Uttar Pradesh	Male	0.65	0.54	0.78
Uttarakhand	Female	1.03	0.74	1.43
Uttarakhand	Male	0.96	0.68	1.35

Abbreviation: CI=Confidence interval.

eTable10. State-level age-standardized diabetes prevalence estimates by rural versus urban location assuming all AHS respondents were unfasted

State	Rural or urban	Diabetes		
		Estimate	Lower 95% CI	Upper 95% CI
Assam	Rural	0.42	0.31	0.57
Assam	Urban	0.86	0.52	1.44
Bihar	Rural	0.27	0.21	0.36
Bihar	Urban	0.58	0.35	0.96
Chhattisgarh	Rural	0.26	0.17	0.40
Chhattisgarh	Urban	0.62	0.45	0.86
Jharkhand	Rural	0.67	0.52	0.87
Jharkhand	Urban	1.99	1.40	2.84
Madhya Pradesh	Rural	0.26	0.21	0.33
Madhya Pradesh	Urban	0.69	0.51	0.92
Odisha	Rural	0.65	0.57	0.73
Odisha	Urban	1.57	1.24	1.98
Rajasthan	Rural	0.28	0.23	0.34
Rajasthan	Urban	0.80	0.63	1.00
Uttar Pradesh	Rural	0.48	0.41	0.57
Uttar Pradesh	Urban	1.24	1.02	1.50
Uttarakhand	Rural	0.76	0.53	1.09
Uttarakhand	Urban	1.57	1.02	2.43

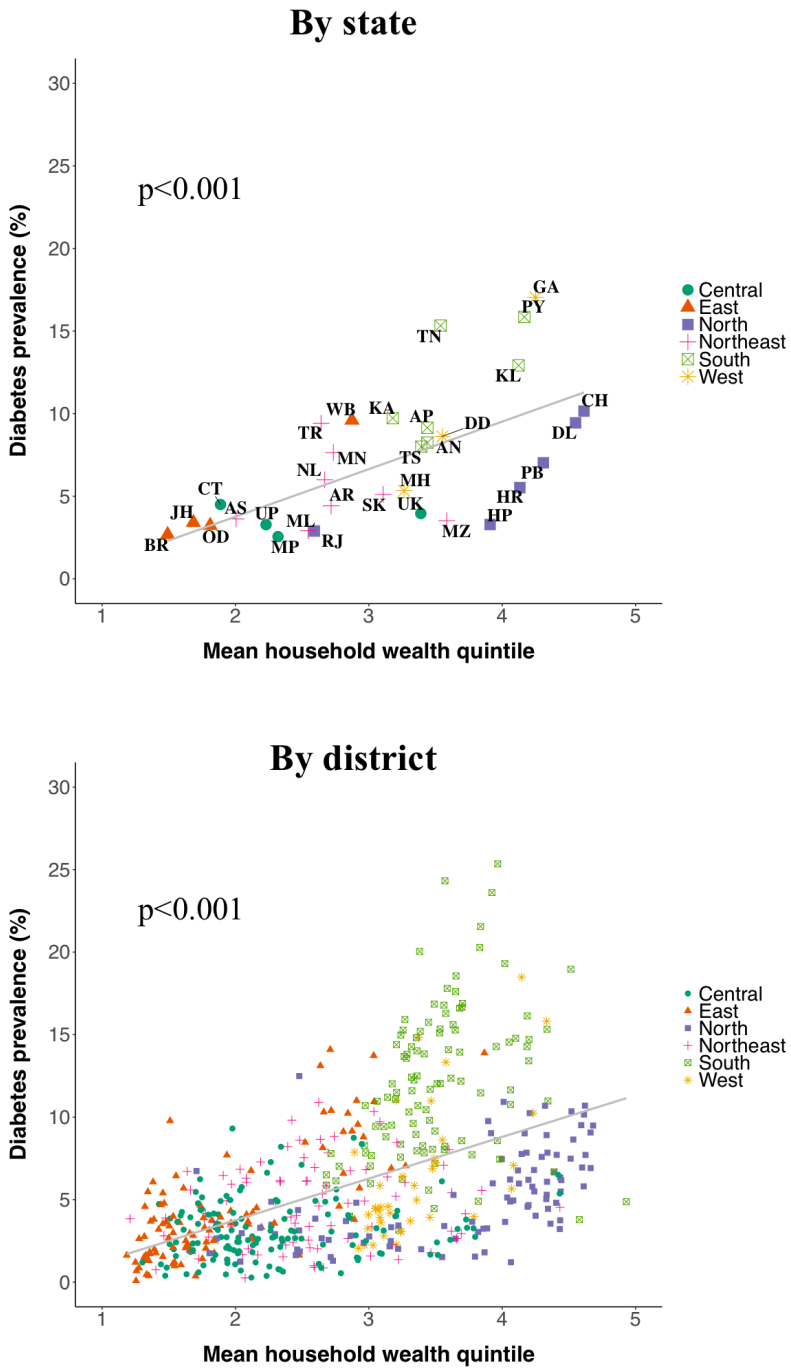
Abbreviation: CI=Confidence interval

eTable11. State-level crude diabetes prevalence estimates by age group assuming all AHS respondents were unfasted

State	Age (years)	Diabetes		
		Estimate	Lower 95% CI	Upper 95% CI
Assam	18-25	0.05	0.02	0.12
Assam	26-35	0.17	0.07	0.40
Assam	36-45	0.61	0.42	0.88
Assam	46-55	0.87	0.62	1.22
Assam	56-65	1.67	1.27	2.20
Assam	>65	1.73	1.20	2.48
Bihar	18-25	0.03	0.01	0.13
Bihar	26-35	0.08	0.04	0.15
Bihar	36-45	0.35	0.25	0.51
Bihar	46-55	0.69	0.48	0.99
Bihar	56-65	1.02	0.74	1.41
Bihar	>65	1.04	0.73	1.50
Chhattisgarh	18-25	0.09	0.03	0.26
Chhattisgarh	26-35	0.13	0.07	0.26
Chhattisgarh	36-45	0.23	0.13	0.40
Chhattisgarh	46-55	0.95	0.61	1.47
Chhattisgarh	56-65	1.28	0.77	2.12
Chhattisgarh	>65	0.94	0.54	1.64
Jharkhand	18-25	0.06	0.02	0.25
Jharkhand	26-35	0.40	0.21	0.74
Jharkhand	36-45	1.06	0.75	1.50
Jharkhand	46-55	2.44	1.80	3.31
Jharkhand	56-65	3.18	2.34	4.30
Jharkhand	>65	2.44	1.73	3.45
Madhya Pradesh	18-25	0.12	0.07	0.21
Madhya Pradesh	26-35	0.16	0.11	0.23
Madhya Pradesh	36-45	0.46	0.35	0.62
Madhya Pradesh	46-55	0.78	0.60	1.03
Madhya Pradesh	56-65	1.59	0.91	2.75
Madhya Pradesh	>65	0.89	0.65	1.22
Odisha	18-25	0.09	0.04	0.19
Odisha	26-35	0.25	0.18	0.35
Odisha	36-45	0.94	0.77	1.17
Odisha	46-55	1.82	1.53	2.16

Odisha	56-65	1.82	1.52	2.17
Odisha	>65	1.38	1.09	1.74
Rajasthan	18-25	0.03	0.01	0.09
Rajasthan	26-35	0.14	0.08	0.24
Rajasthan	36-45	0.36	0.26	0.50
Rajasthan	46-55	1.05	0.80	1.37
Rajasthan	56-65	1.17	0.91	1.50
Rajasthan	>65	1.53	1.09	2.14
Uttar Pradesh	18-25	0.08	0.04	0.14
Uttar Pradesh	26-35	0.18	0.12	0.26
Uttar Pradesh	36-45	0.82	0.64	1.04
Uttar Pradesh	46-55	1.75	1.43	2.14
Uttar Pradesh	56-65	1.96	1.57	2.43
Uttar Pradesh	>65	1.29	1.00	1.67
Uttarakhand	18-25	0.25	0.04	1.38
Uttarakhand	26-35	0.16	0.05	0.52
Uttarakhand	36-45	1.09	0.65	1.82
Uttarakhand	46-55	1.70	1.08	2.66
Uttarakhand	56-65	3.98	2.78	5.69
Uttarakhand	>65	2.91	1.99	4.25

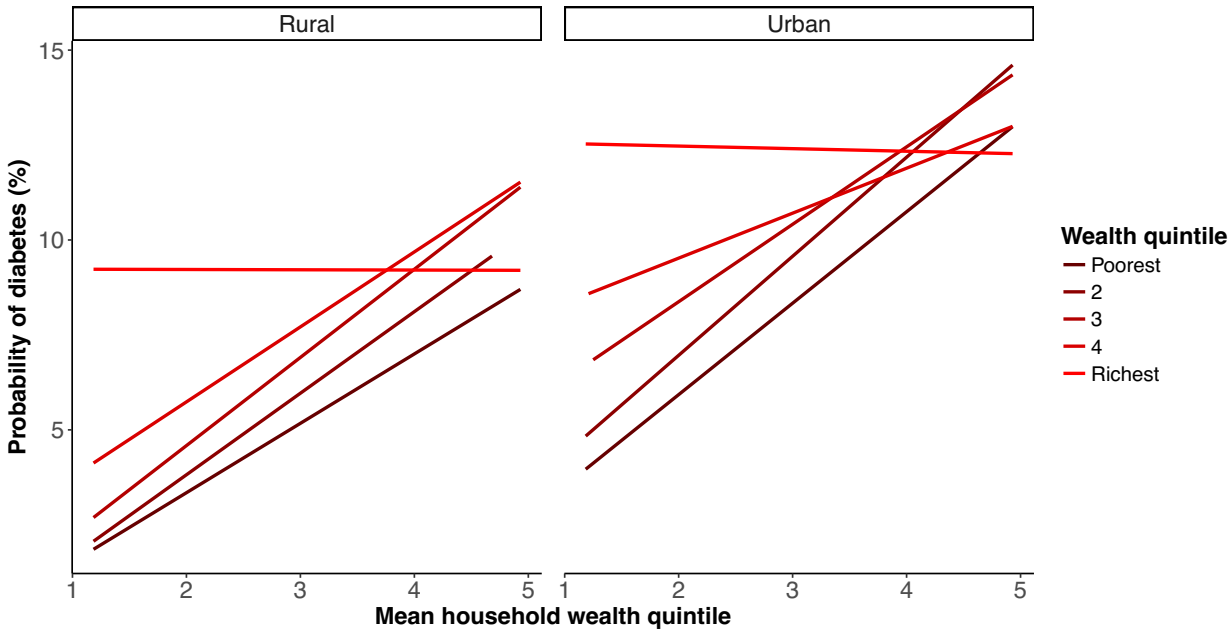
eFigure8. Association of the state- and district-level age-standardized prevalence of diabetes with mean household wealth quintile[a,b]



[a] p-values refer to the statistical significance of the linear (ordinary least squares) regression line (shown in grey).
[b] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]

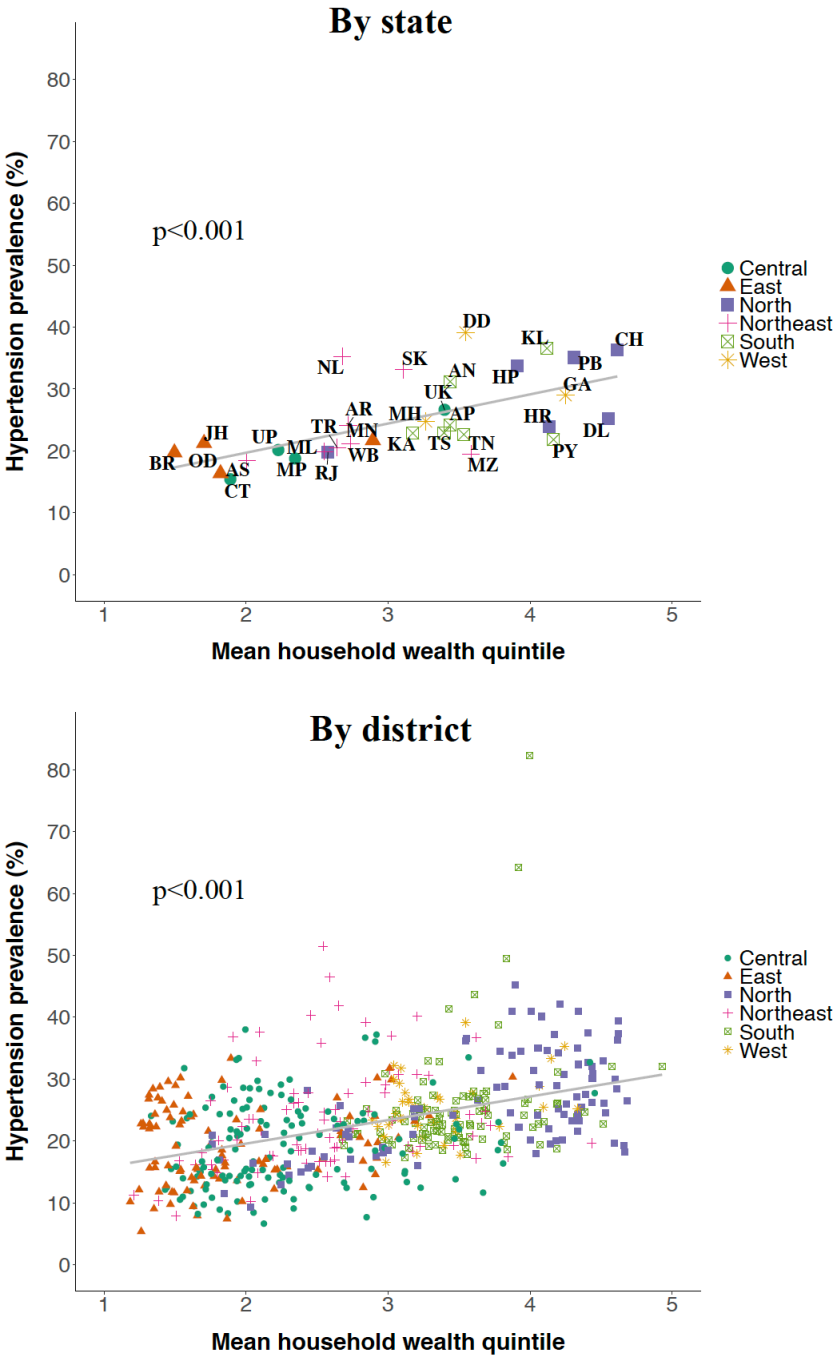
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CH, Chandigarh; CT, Chhattisgarh; DD, Daman and Diu; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; PY, Puducherry; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

eFigure9. Predicted probability of diabetes from a multilevel linear probability model[1]



[1] These predicted probabilities were obtained from a multilevel linear probability model with age (group-mean centered and normalized), sex, rural-urban location, household wealth quintile, and education as level 1 variables, and district-level mean household wealth quintile (grand-mean centered) as level 2 variable. The model included a random intercept at the level of the district and random slopes for household wealth quintile.

eFigure10. Association of the state- and district-level age-standardized prevalence of hypertension with mean household wealth quintile[a,b]

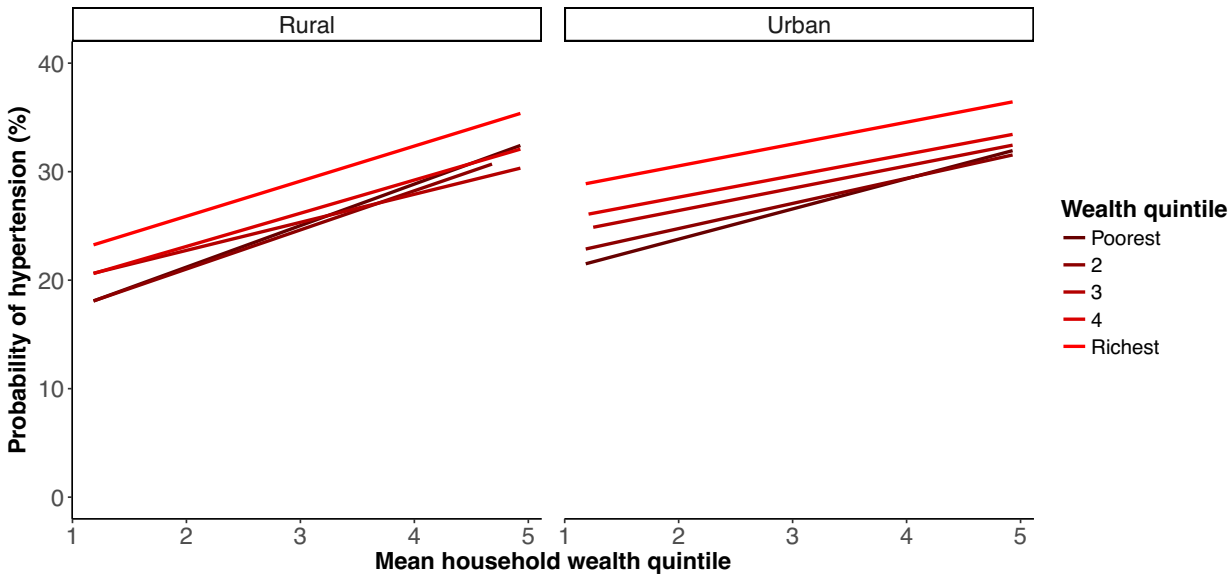


[a] p-values refer to the statistical significance of the linear (ordinary least squares) regression line (shown in grey).
[b] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]

Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CH, Chandigarh; CT, Chhattisgarh; DD, Daman and Diu; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK,

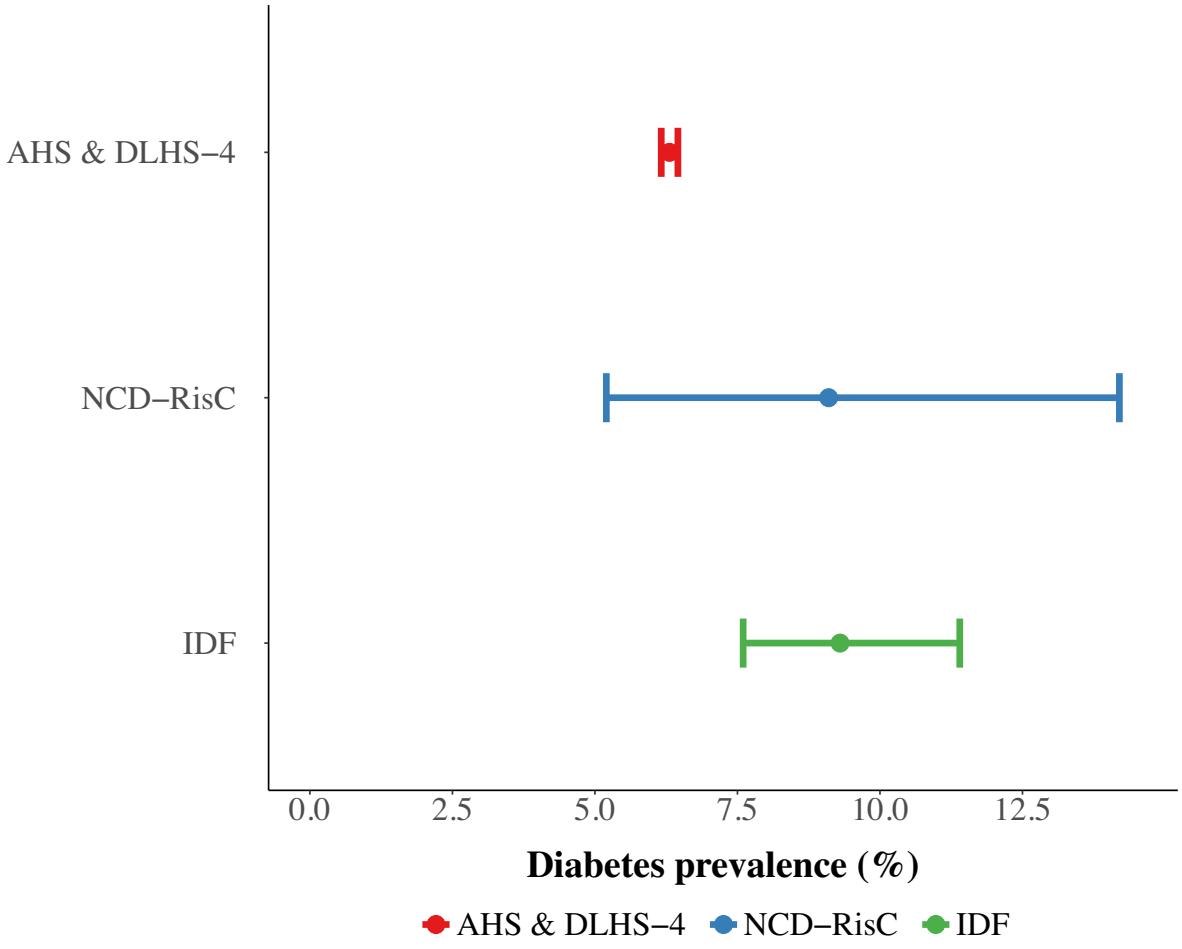
Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; PY, Puducherry; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

eFigure11. Predicted probability of hypertension from a multilevel linear probability model[1]



[1] These predicted probabilities were obtained from a multilevel linear probability model with age (group-mean centered and normalized), sex, rural-urban location, household wealth quintile, and education as level 1 variables, and district-level mean household wealth quintile (grand-mean centered) as level 2 variable. The model included a random intercept at the level of the district and random slopes for household wealth quintile.

eFigure12. Comparison of age-standardized national diabetes prevalence reported in different studies[a,b]



Abbreviations: NCD-RisC = NCD Risk Factor Collaboration; IDF = International Diabetes Federation

[a] The NCD-RisC estimate is for 2014 and the IDF estimate for 2015.[83,120]

[b] The horizontal bar is a 95% confidence interval (AHS & DLHS-4) or a 95% uncertainty interval (NCD-RisC and IDF).

eMethods5. Matching AHS biomarker data to participants' sociodemographic data

AHS data in the public domain does not have a unique identifier that allows for merging of the 'laboratory dataset', which contains height, weight, blood pressure, and blood glucose measurements, to the dataset that contains respondents' full sociodemographic and treatment information. We thus merged these datasets using an indicator composed of the state, district, stratum (indicating rural versus urban location and village size), a household identifier that is unique within each PSU, and a household member serial number given during data entry as well as one assigned after data entry.

415,728 out of 661,141 (62.9%) non-pregnant adults aged 30 to 74 years in the laboratory dataset were successfully matched to their corresponding sociodemographic and treatment information. As detailed in the tables below, participants who were not matched had similar characteristics as those who were matched.

Across all nine AHS states:

Variable	**Matched**	**Not matched**
	n= 415,728	*n=245,413*
Male (%)	49.8	49.0
Age (mean ± SD)	46.5±11.7	47.1±12.3
Glucose (mean ± SD)	99.0±21.3	99.2±21.6
Diabetes (%)	4.6	4.6
Systolic BP (mean ± SD)	125.4±19.3	125.6±19.9
BMI (mean ± SD)	21.2±3.7	21.2±3.7
Urban (%)	19.3	18.3

Abbreviations: SD=standard deviation

Assam:

Variable	**Matched**	**Not matched**
	n=44,479	*n=13,132*
Male (%)	51.3	47.1
Age (mean ± SD)	45.4±11.2	45.6±12.0
Glucose (mean ± SD)	99.8±21.0	99.8±21.2
Diabetes (%)	5.2	5.4
Systolic BP (mean ± SD)	128.1±18.0	127.2±18.4
BMI (mean ± SD)	21.5±3.3	21.1±3.5
Urban (%)	17.1	23.1

Abbreviations: SD=standard deviation

Bihar:

Variable	Matched	Not matched
	n=49,213	*n=45,723*
Male (%)	48.4	53.5
Age (mean ± SD)	46.4±11.8	46.6±12.3
Glucose (mean ± SD)	97.0±18.9	95.2±18.4
Diabetes (%)	3.9	3.4
Systolic BP (mean ± SD)	125.4±19.0	123.8±18.3
BMI (mean ± SD)	20.7±3.1	20.9±3.1
Urban (%)	9.9	8.3

Abbreviations: SD=standard deviation

Chhattisgarh:

Variable	Matched	Not matched
	n=26,035	*n= 12,185*
Male (%)	51.0	49.2
Age (mean ± SD)	45.8±11.3	46.5±12.0
Glucose (mean ± SD)	100.5±18.2	101.2±21.1
Diabetes (%)	5.5	6.6
Systolic BP (mean ± SD)	125.2±17.1	126.1±17.8
BMI (mean ± SD)	21.2±3.3	21.3±3.4
Urban (%)	19.4	23.2

Abbreviations: SD=standard deviation

Jharkhand:

Variable	Matched	Not matched
	n=24,645	*n=11,255*
Male (%)	44.5	45.0
Age (mean ± SD)	46.3±11.7	47.3±12.3
Glucose (mean ± SD)	96.9±24.9	96.6±22.5
Diabetes (%)	5.1	4.7
Systolic BP (mean ± SD)	125.6±20.7	126.7±21.0
BMI (mean ± SD)	21.2±4.1	21.2±3.9
Urban (%)	17.5	22.7

Abbreviations: SD=standard deviation

Madhya Pradesh:

Variable	Matched	Not matched
	n=67,506	*n=37,172*
Male (%)	53.2	52.1
Age (mean ± SD)	46.0±11.7	46.7±12.2
Glucose (mean ± SD)	97.9±19.2	98.0±18.6
Diabetes (%)	3.7	3.5
Systolic BP (mean ± SD)	126.3±18.2	126.7±17.9
BMI (mean ± SD)	21.2±3.2	21.2±3.3
Urban (%)	32.6	29.2

Abbreviations: SD=standard deviation

Odisha:

Variable	Matched	Not matched
	n=65,511	*n=12,034*
Male (%)	49.2	45.6
Age (mean ± SD)	47.0±11.8	47.9±12.3
Glucose (mean ± SD)	98.7±23.5	99.0±24.5
Diabetes (%)	5.0	5.2
Systolic BP (mean ± SD)	122.7±20.2	123.4±20.7
BMI (mean ± SD)	21.2±4.0	21.3±4.1
Urban (%)	14.0	13.8

Abbreviations: SD=standard deviation

Rajasthan:

Variable	Matched	Not matched
	n=55,928	*n=13,682*
Male (%)	47.8	46.3
Age (mean ± SD)	46.6±11.7	47.3±12.5
Glucose (mean ± SD)	100.1±20.1	100.2±19.9
Diabetes (%)	4.4	4.3
Systolic BP (mean ± SD)	124.8±19.0	125.4±19.5
BMI (mean ± SD)	21.4±4.0	21.4±4.1
Urban (%)	17.6	17.7

Abbreviations: SD=standard deviation

Uttar Pradesh:

Variable	Matched	Not matched
	n=68,497	*n=88,121*
Male (%)	50.7	47.9
Age (mean ± SD)	47.0±11.9	47.6±12.5
Glucose (mean ± SD)	100.9±22.0	101.1±22.9
Diabetes (%)	4.8	4.9
Systolic BP (mean ± SD)	124.9±20.6	125.8±21.4
BMI (mean ± SD)	21.2±3.9	21.0±3.9
Urban (%)	20.7	17.3

Abbreviations: SD=standard deviation

Uttarakhand:

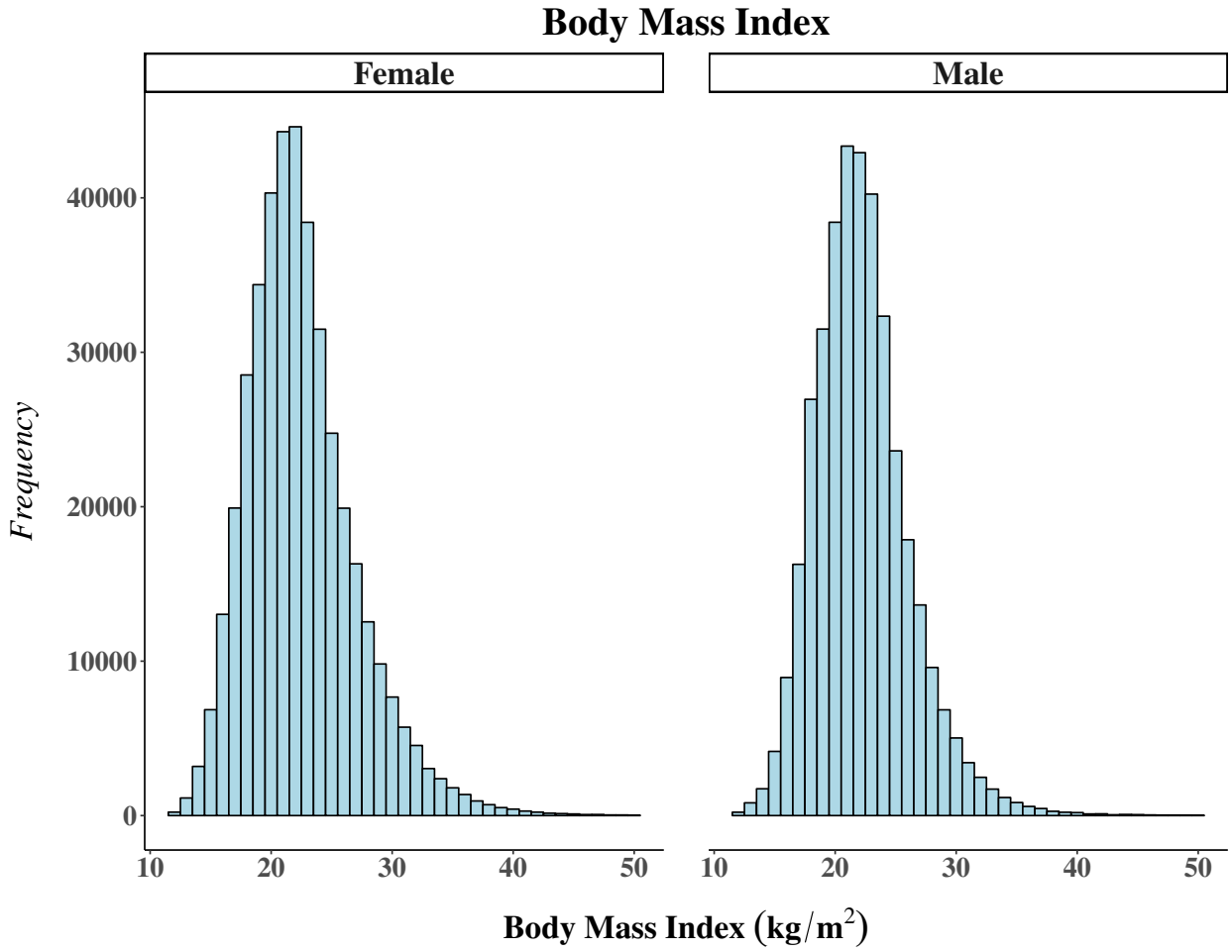
Variable	Matched	Not matched
	n=13,914	*n=12,109*
Male (%)	46.3	42.2
Age (mean ± SD)	48.0±12.1	47.7±12.3
Glucose (mean ± SD)	100.1±24.4	103.2±26.8
Diabetes (%)	5.6	5.6
Systolic BP (mean ± SD)	129.6±19.7	127.2±20.9
BMI (mean ± SD)	22.9±4.0	22.7±4.3
Urban (%)	21.7	21.2

Abbreviations: SD=standard deviation

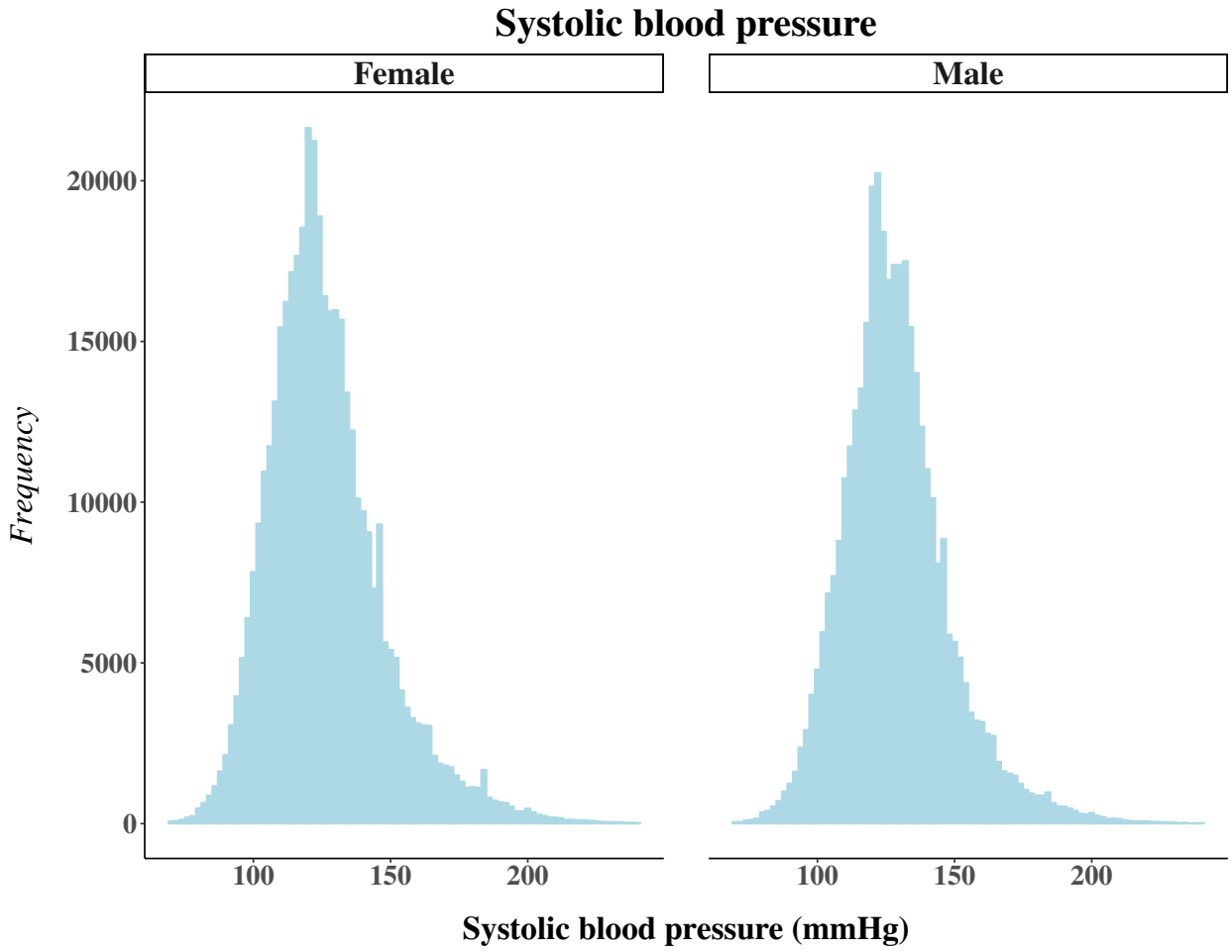
eTable12. Outcomes predicted by each cardiovascular risk score

	Framingham[21]	Harvard-NHANES[23]	Globorisk[22]	WHO-ISH[24]
Fatal outcomes	• Any coronary disease • Stroke	• Any coronary disease • Stroke	• Myocardial infarction • Stroke • Sudden cardiac death	• Myocardial infarction • Stroke
Non-fatal outcomes	• Angina pectoris • Coronary insufficiency • Heart failure • Myocardial infarction • Peripheral artery disease • Stroke • Transient ischemic attack	• Congestive heart failure • Coronary revascularization • Myocardial infarction • Stroke	• Myocardial infarction • Stroke	• Myocardial infarction • Stroke

eFigure13. Histogram of Body Mass Index



eFigure14. Histogram of systolic blood pressure



eTable13. Characteristics of adults excluded from the analysis

In total, 27.1% (296,822/1,094,754) of participants were excluded from the analysis because they had a missing value for at least one of the cardiovascular disease risk factors needed to compute a predicted cardiovascular risk (age, sex, Body Mass Index, blood glucose, smoking status, systolic blood pressure, and treatment for hypertension). The table below compares (by sex) the sampling characteristics of those who were excluded from the analysis with those who were included.

Characteristic	Female		Male	
	Included	*Excluded*	*Included*	*Excluded*
n	420,852	108,937	377,080	187,885
Cardiovascular risk factors				
Age group (%)				
30-34 years	17.2	18.3	15.3	18.6
35-39 years	17.0	16.5	15.0	16.5
40-44 years	15.3	14.0	14.8	15.1
45-49 years	13.2	11.6	13.4	12.9
50-54 years	11.7	11.6	11.8	11.0
55-59 years	8.8	8.9	9.6	8.6
60-64 years	7.6	8.2	8.7	7.7
65-69 years	5.6	6.3	6.7	5.5
70-74 years	3.6	4.7	4.7	4.0
Mean BMI in kg/m^2 (SD)	22.6 (4.8)	22.5 (4.8)	22.3 (4.1)	22.1 (4.1)
BMI (%)				
<18.5 kg/m^2	17.3	17.6	15.7	16.8
18.5-22.9 kg/m^2	43.6	44.6	46.9	47.1
23.0-24.9 kg/m^2	15.1	15.0	17.2	17.2
25.0-29.9 kg/m^2	17.6	16.8	16.3	15.3
≥30.0 kg/m^2	6.4	5.9	3.9	3.5
Diabetes (%)	10.0	10.0	10.8	12.9
Current smoking (%)	2.6	2.6	27.1	27.9
Mean systolic BP in mmHg (SD)	126.7 (21.3)	126.4 (21.3)	129.1 (19.7)	128.6 (19.5)
Systolic BP (%)				
<120 mmHg	40.1	40.1	31.4	31.6
120 – 129 mmHg	22.1	22.4	24.6	24.9
130 – 139 mmHg	15.7	15.9	20.0	21.1
140 – 179 mmHg	19.4	19.2	21.9	20.6
≥180 mmHg	2.6	2.4	2.1	1.8
Current treatment for hypertension	2.3	2.1	1.7	1.4
Socio-demographic characteristics				
Educational attainment (%)				

<Primary School	56.4	57.1	34.1	30.6
Primary School	12.1	11.2	13.6	12.3
Middle School	12.0	11.5	16.2	16.2
Secondary School	9.6	8.9	15.8	16.9
High School	4.7	4.9	8.8	9.9
>High School	5.3	6.3	11.5	14.0
Urban area (%)	32.4	32.6	32.2	36.8
Wealth quintile (%)				
1 (poorest)	21.6	17.4	21.0	15.2
2	19.9	18.8	19.8	17.9
3	19.1	20.0	19.1	20.4
4	19.4	21.5	19.8	22.2
5 (richest)	20.0	22.3	20.2	24.3

eTable14. Prevalence of high 10-year cardiovascular risk and mean risk, by age group

Age	Percentage at high risk[1]		Mean risk	
	Female (95% CI)	***Male*** (95% CI)	***Female*** (95% CI)	***Male*** (95% CI)
30-34 years	0.0 (0.0, 0.0)	0.1 (0.0, 0.1)	3.9 (3.9, 3.9)	6.1 (6.1, 6.2)
35-39 years	0.2 (0.2, 0.2)	0.8 (0.7, 0.9)	6.3 (6.3, 6.3)	10.1 (10.0, 10.2)
40-44 years	1.5 (1.4, 1.6)	4.7 (4.4, 5.0)	9.7 (9.6, 9.7)	15.1 (15.0, 15.2)
45-49 years	6.2 (5.9, 6.6)	18.1 (17.6, 18.7)	14.2 (14.1, 14.3)	21.6 (21.5, 21.8)
50-54 years	14.8 (14.2, 15.3)	38.0 (37.1, 38.8)	19.5 (19.3, 19.7)	28.9 (28.7, 29.1)
55-59 years	26.9 (26.2, 27.7)	60.3 (59.4, 61.1)	25.4 (25.1, 25.6)	37.1 (36.8, 37.4)
60-64 years	43.7 (42.8, 44.6)	80.0 (79.3, 80.7)	32.2 (31.8, 32.5)	44.8 (44.5, 45.1)
65-69 years	59.4 (58.5, 60.4)	91.5 (90.9, 92.0)	38.0 (37.7, 38.4)	51.9 (51.5, 52.2)
70-74 years	73.1 (72.0, 74.1)	96.9 (96.6, 97.3)	44.3 (43.8, 44.7)	58.7 (58.3, 59.1)
30-74 years	*14.6 (14.4, 14.8)*	*31.7 (31.4, 32.0)*	*12.7 (12.7, 12.8)*	*21.4 (21.3, 21.6)*
50-74 years	*36.1 (35.6, 36.5)*	*67.6 (67.1, 68.1)*	*28.7 (28.6, 28.9)*	*41.4 (41.2, 41.6)*

Abbreviation: CI=confidence interval.

[1] Defined as a 10-year cardiovascular risk ≥30% as computed with the Framingham risk score.

eTable15. Prevalence of a high 10-year cardiovascular risk (risk ≥30%) and mean risk as calculated by Harvard-NHANES and Globorisk

	Harvard-NHANES		Globorisk[1]		WHO-ISH[2]	
	Female (95% CI)	***Male*** (95% CI)	***Female*** (95% CI)	***Male*** (95% CI)	***Female*** (95% CI)	***Male*** (95% CI)
% at high risk						
30-34 years	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	-	-	0.0 (0.0, 0.1)	0.1 (0.1, 0.2)
35-39 years	0.0 (0.0, 0.0)	0.1 (0.1, 0.1)	-	-	0.1 (0.1, 0.1)	0.2 (0.2, 0.3)
40-44 years	0.0 (0.0, 0.1)	1.1 (1.0, 1.2)	0.0 (0.0, 0.0)	0.5 (0.4, 0.6)	0.2 (0.2, 0.3)	0.4 (0.3, 0.5)
45-49 years	0.8 (0.7, 0.9)	6.9 (6.6, 7.3)	0.1 (0.1, 0.2)	1.7 (1.5, 1.9)	0.4 (0.3, 0.5)	0.8 (0.7, 0.9)
50-54 years	5.4 (5.0, 5.8)	23.3 (22.7, 24.0)	0.7 (0.6, 0.8)	3.0 (2.8, 3.2)	3.0 (2.7, 3.2)	2.4 (2.2, 2.6)
55-59 years	15.3 (14.8, 15.9)	47.7 (46.9, 48.6)	1.9 (1.7, 2.1)	4.6 (4.2, 4.9)	4.2 (3.9, 4.5)	3.5 (3.2, 3.8)
60-64 years	33.8 (33.0, 34.7)	73.8 (73.1, 74.5)	4.4 (4.1, 4.7)	5.8 (5.4, 6.2)	8.6 (8.2, 9.1)	8.4 (8.0, 8.9)
65-69 years	58.5 (57.5, 59.5)	91.2 (90.7, 91.8)	6.9 (6.5, 7.4)	7.0 (6.6, 7.4)	9.5 (9.0, 10.0)	9.5 (9.0, 10.0)
70-74 years	82.6 (81.7, 83.5)	98.0 (97.7, 98.2)	13.2 (12.4, 13.9)	11.0 (10.3, 11.8)	15.7 (14.9, 16.5)	11.0 (10.2, 11.7)
30-74 years	*11.1 (10.9, 11.2)*	*26.1 (25.9, 26.4)*	-	-	*2.6 (2.5, 2.7)*	*2.8 (2.7, 2.9)*
50-74 years	*29.2 (28.8, 29.6)*	*59.4 (58.9, 59.9)*	*3.9 (3.7, 4.0)*	*5.5 (5.3, 5.7)*	*6.7 (6.5, 6.8)*	*6.1 (5.9, 6.3)*
Mean risk (%)						
30-34 years	2.0 (2.0, 2.0)	4.0 (4.0, 4.0)	-	-	-	-
35-39 years	3.7 (3.7, 3.7)	7.1 (7.0, 7.1)	-	-	-	-
40-44 years	6.3 (6.2, 6.3)	11.3 (11.2, 11.3)	3.7 (3.7, 3.7)	7.9 (7.8, 7.9)	-	-
45-49 years	10.1 (10.1, 10.2)	17.1 (17.0, 17.2)	5.5 (5.5, 5.6)	11.0 (10.9, 11.1)	-	-
50-54 years	15.2 (15.1, 15.4)	24.1 (24.0, 24.3)	8.2 (8.2, 8.3)	13.5 (13.3, 13.6)	-	-
55-59 years	21.2 (21.0, 21.3)	32.6 (32.3, 32.8)	11.5 (11.4, 11.6)	15.3 (15.2, 15.5)	-	-
60-64 years	28.5 (28.3, 28.8)	40.9 (40.7, 41.2)	14.9 (14.8, 15.0)	17.0 (16.8, 17.1)	-	-
65-69 years	35.8 (35.5, 36.1)	49.0 (48.7, 49.4)	17.2 (17.1, 17.4)	18.4 (18.3, 18.5)	-	-
70-74 years	43.5 (43.2, 43.9)	57.2 (56.8, 57.5)	21.1 (20.9, 21.3)	20.9 (20.7, 21.1)	-	-
30-74 years	15.9 (15.8, 16.0)	25.0 (24.9, 25.1)	-	-	-	-
50-74 years	25.3 (25.1, 25.4)	37.6 (37.4, 37.7)	13.0 (12.9, 13.1)	16.3 (16.2, 16.4)	-	-

Abbreviation: CI=confidence interval.

[1] The Globorisk score predicts cardiovascular risk for adults aged 40-74 years only.

[2] WHO-ISH computes a risk category rather than a continuous risk score. It was, therefore, not possible to estimate mean risk for WHO-ISH.

eTable16. Proportion of participants who were overweight, current smokers, hypertensive, or had diabetes

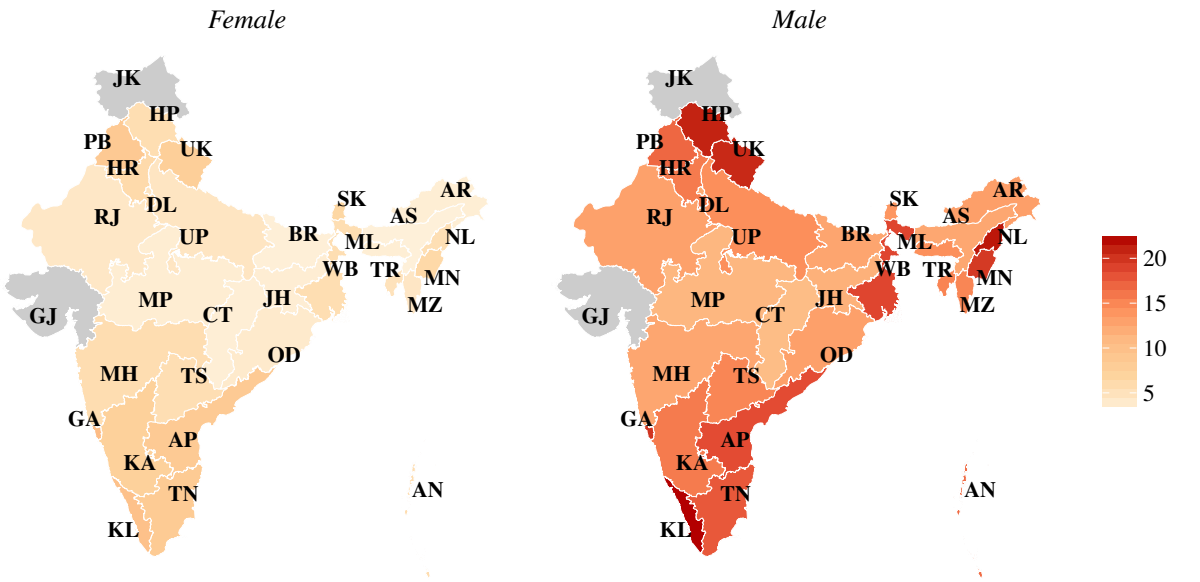
The table below shows the proportion of participants who were either current smokers, had diabetes, hypertension, or who were overweight. Diabetes was defined as having a high blood glucose reading or reporting to be on regular treatment for diabetes. Hypertension was defined as a systolic blood pressure ≥140mmHg, a diastolic blood pressure ≥90mmHg, or reporting to be on regular treatment for hypertension. Overweight was defined as a Body Mass Index ≥25kg/m^2. The proportions shown were weighted using sampling weights (but not age-standardized).

Age	***Female*** (95% CI)	***Male*** (95% CI)
30-34 years	32.26 (31.60 - 32.93)	49.31 (48.58 - 50.04)
35-39 years	38.22 (37.56 - 38.88)	55.79 (55.06 - 56.53)
40-44 years	43.66 (42.95 - 44.38)	59.74 (58.97 - 60.52)
45-49 years	49.15 (48.43 - 49.87)	63.73 (62.99 - 64.47)
50-54 years	54.14 (53.32 - 54.96)	66.15(65.29 – 67.00)
55-59 years	56.00 (55.13 - 56.87)	68.37 (67.57 - 69.18)
60-64 years	60.90 (59.98 - 61.81)	70.04 (69.26 - 70.82)
65-69 years	61.48 (60.48 - 62.49)	69.63 (68.72 - 70.53)
70-74 years	63.39 (62.20 - 64.56)	70.00 (68.99 - 71.01)
30-74 years	*53.0 (52.5 - 53.5)*	*67.2 (66.8 - 67.7)*
50-74 years	*46.84 (46.36 - 47.33)*	*61.82 (61.36 - 62.27)*

eFigure15. Age-standardized prevalence of a 10-year cardiovascular risk ≥30% as estimated by the Harvard-NHANES score, by state[1]

[1] The Union Territories, Chandigarh, Daman and Diu, and Puducherry are not visible in the map due to their small area.

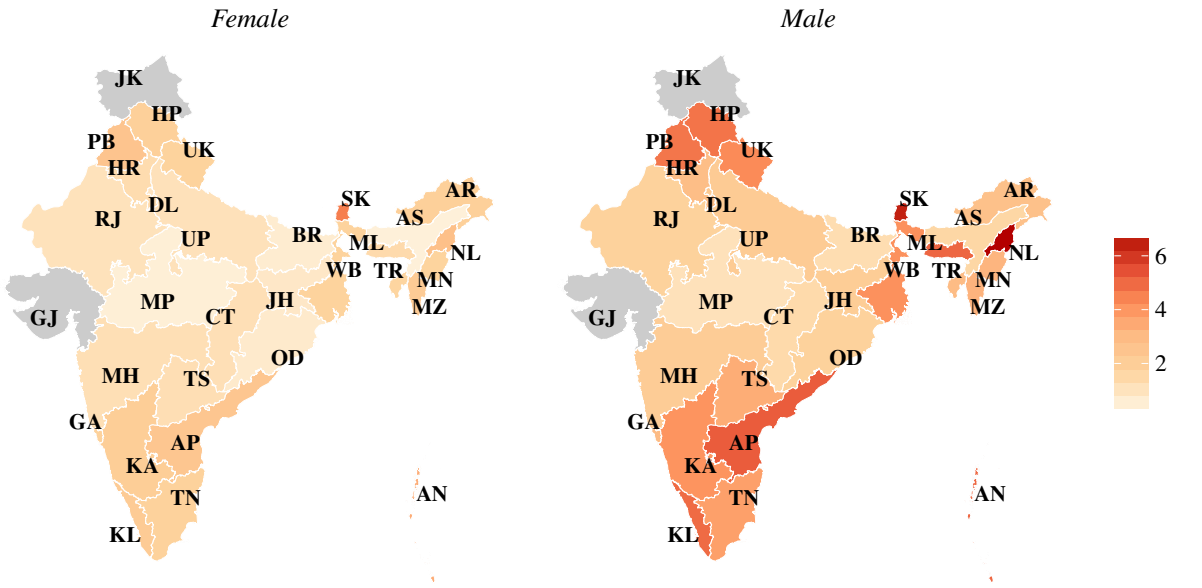
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CT, Chhattisgarh; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.



eFigure16. Age-standardized prevalence of a 10-year cardiovascular risk ≥30% as estimated by Globorisk, by state[1]

[1] The Union Territories, Chandigarh, Daman and Diu, and Puducherry are not visible in the map due to their small area.

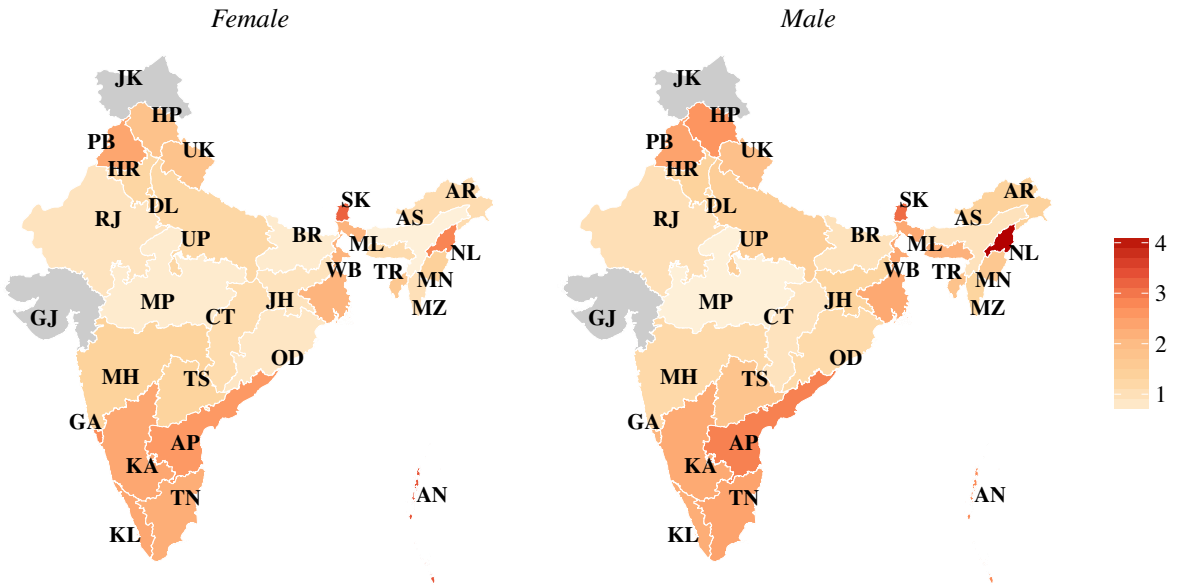
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CT, Chhattisgarh; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.



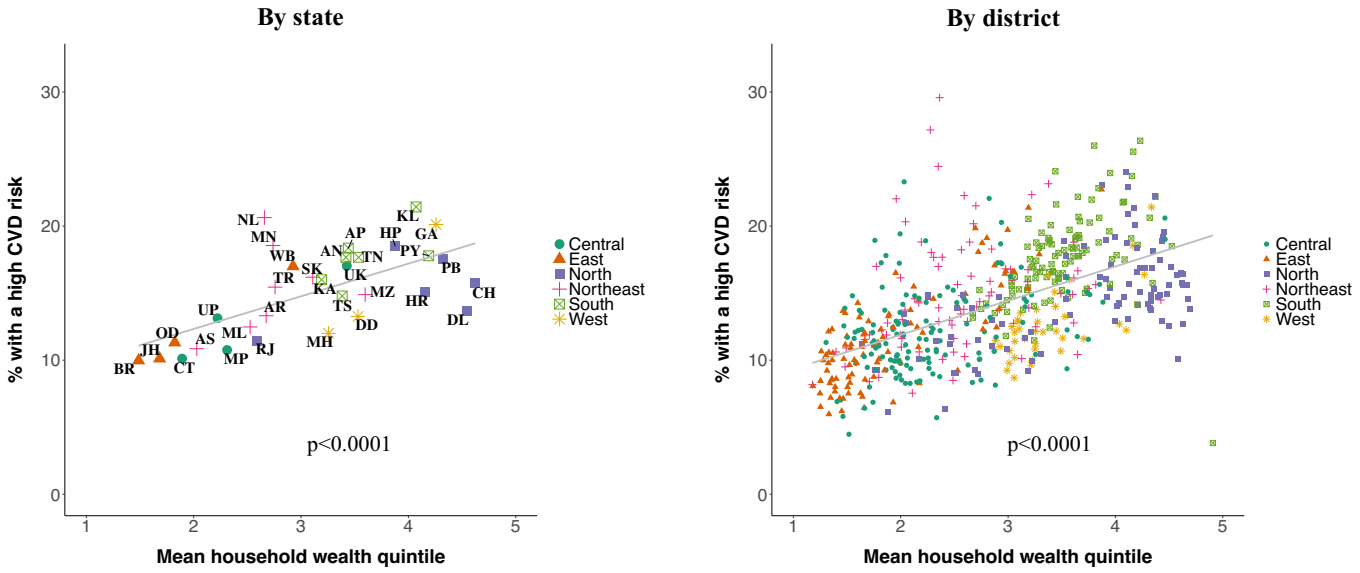
eFigure17. Age-standardized prevalence of a 10-year cardiovascular risk ≥30% as estimated by WHO-ISH, by state[1]

[1] The Union Territories, Chandigarh, Daman and Diu, and Puducherry are not visible in the map due to their small area.

Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CT, Chhattisgarh; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.



eFigure18. Association between an area's standard of living and high cardiovascular disease risk[1,2,3,4,5]



[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] The proportion of people in a state/district that is at high CVD risk has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] P-values refer to the statistical significance of the linear (ordinary least squares) regression line (shown in grey).
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CH, Chandigarh; CT, Chhattisgarh; DD, Daman and Diu; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; PY, Puducherry; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

eTable17. Prevalence of a high (≥30%) 10-year cardiovascular risk, by state and sex

State	*Sex*	Framingham[1]			Harvard-NHANES[1]			Globorisk[1]		
		Estimate	*Lower CI*	*Upper CI*	*Estimate*	*Lower CI*	*Upper CI*	*Estimate*	*Lower CI*	*Upper CI*
Andaman and Nicobar	Female	12.4	10.6	14.4	5.8	4.7	6.9	3.4	2.3	4.7
Andaman and Nicobar	Male	22.8	20.7	25.0	16.6	14.6	18.7	5.0	3.6	6.7
Andhra Pradesh	Female	12.7	12.1	13.3	8.5	8.0	8.9	2.4	2.1	2.7
Andhra Pradesh	Male	24.2	23.3	25.1	18.4	17.7	19.1	5.3	4.8	5.8
Arunachal Pradesh	Female	6.4	5.7	7.1	3.5	2.8	4.2	1.9	1.2	2.7
Arunachal Pradesh	Male	20.1	18.9	21.4	13.1	12.1	14.2	2.7	2.2	3.2
Assam	Female	5.0	4.5	5.6	3.1	2.8	3.5	0.4	0.3	0.5
Assam	Male	17.2	15.9	18.6	12.5	11.5	13.5	1.5	1.3	1.9
Bihar	Female	5.2	4.7	5.6	3.3	3.0	3.5	0.6	0.5	0.7
Bihar	Male	16.6	15.6	17.6	12.6	11.8	13.4	1.3	1.0	1.5
Chandigarh	Female	9.9	8.3	11.5	5.8	4.8	6.9	0.7	0.4	1.2
Chandigarh	Male	21.7	18.8	24.8	14.9	12.5	17.4	2.6	1.7	3.8
Chhattisgarh	Female	5.5	4.7	6.3	3.4	2.9	4.0	1.2	0.8	1.7
Chhattisgarh	Male	14.4	13.2	15.6	10.5	9.5	11.7	1.4	1.0	1.9
Daman and Diu	Female	10.6	8.4	12.9	6.1	4.4	8.1	1.7	0.8	2.9
Daman and Diu	Male	17.8	12.9	23.4	11.3	7.9	15.4	3.7	1.3	7.3
Goa	Female	15.5	13.7	17.3	10.6	9.3	11.9	1.8	1.2	2.4
Goa	Male	25.8	23.2	28.5	19.9	17.6	22.3	2.9	1.7	4.5
Haryana	Female	8.3	8.0	8.7	6.1	5.8	6.4	1.3	1.1	1.5
Haryana	Male	21.4	20.8	22.0	15.7	15.2	16.2	2.8	2.5	3.1
Himachal Pradesh	Female	9.2	8.4	10.0	5.7	5.1	6.2	1.9	1.6	2.3
Himachal Pradesh	Male	29.3	27.7	30.9	21.0	19.7	22.3	4.8	4.0	5.7
Jharkhand	Female	6.2	5.5	6.9	3.5	3.1	4.0	0.8	0.6	1.0
Jharkhand	Male	15.4	14.2	16.6	11.7	10.7	12.7	2.1	1.6	2.6
Karnataka	Female	11.8	11.4	12.1	7.4	7.1	7.6	2.0	1.9	2.2

Karnataka	Male	20.8	20.4	21.3	15.7	15.3	16.1	4.1	3.8	4.4
Kerala	Female	14.3	13.6	14.9	9.9	9.4	10.5	2.1	1.9	2.5
Kerala	Male	30.4	28.8	32.0	22.4	21.2	23.6	5.1	4.4	5.8
Madhya Pradesh	Female	5.3	4.6	6.2	3.6	3.1	4.1	0.5	0.3	0.6
Madhya Pradesh	Male	15.7	15.0	16.5	11.1	10.6	11.7	1.1	0.8	1.4
Maharashtra	Female	8.2	7.9	8.5	5.8	5.5	6.0	1.2	1.1	1.3
Maharashtra	Male	16.2	15.8	16.6	12.5	12.2	12.9	2.1	1.9	2.3
Manipur	Female	9.1	8.5	9.8	6.3	5.8	6.8	1.7	1.4	2.1
Manipur	Male	28.4	27.3	29.6	19.5	18.6	20.4	3.1	2.7	3.7
Meghalaya	Female	6.3	5.5	7.1	3.4	2.9	4.0	1.4	1.0	1.8
Meghalaya	Male	21.7	20.1	23.4	14.4	13.1	15.8	5.1	4.0	6.2
Mizoram	Female	6.5	6.0	7.1	4.4	4.1	4.8	2.2	1.7	2.6
Mizoram	Male	23.1	22.1	24.0	15.0	14.2	15.7	3.2	2.7	3.7
Nagaland	Female	10.7	9.7	11.7	5.5	4.9	6.1	2.8	2.2	3.3
Nagaland	Male	30.2	28.5	31.9	21.4	20.0	22.9	6.9	6.0	7.8
NCT of Delhi	Female	8.5	7.7	9.3	4.7	4.2	5.3	0.9	0.6	1.3
NCT of Delhi	Male	17.4	16.4	18.6	12.1	11.3	13.0	2.3	1.8	2.8
Odisha	Female	6.3	5.9	6.7	4.0	3.7	4.3	0.7	0.6	0.8
Odisha	Male	16.9	16.1	17.7	13.1	12.5	13.7	1.8	1.6	2.1
Puducherry	Female	14.5	13.6	15.5	9.9	9.1	10.7	1.9	1.5	2.4
Puducherry	Male	22.1	20.5	23.8	18.1	16.7	19.5	3.8	3.0	4.6
Punjab	Female	12.9	12.5	13.3	8.6	8.3	8.9	2.5	2.3	2.7
Punjab	Male	22.7	22.2	23.3	16.9	16.4	17.3	4.8	4.4	5.1
Rajasthan	Female	6.3	5.8	6.8	4.4	4.0	4.8	1.1	0.9	1.2
Rajasthan	Male	17.9	16.8	19.1	13.0	12.2	13.9	1.8	1.5	2.2
Sikkim	Female	12.3	11.2	13.4	6.6	5.9	7.4	4.6	3.7	5.6
Sikkim	Male	20.0	18.7	21.4	13.9	12.7	15.1	6.5	5.2	7.8
Tamil Nadu	Female	13.3	12.9	13.7	8.4	8.1	8.7	1.8	1.6	1.9
Tamil Nadu	Male	22.7	22.2	23.2	17.7	17.3	18.1	3.8	3.5	4.0

Telangana	Female	8.4	7.8	9.1	5.6	5.1	6.1	1.2	0.9	1.5
Telangana	Male	20.3	19.4	21.3	15.1	14.3	15.9	3.4	2.9	3.9
Tripura	Female	9.2	7.9	10.5	5.1	4.3	5.9	1.7	1.0	2.4
Tripura	Male	21.4	19.3	23.5	15.2	13.6	16.9	3.0	2.2	3.9
Uttar Pradesh	Female	7.2	6.7	7.7	4.6	4.3	5.0	1.1	0.9	1.3
Uttar Pradesh	Male	19.9	19.0	20.8	14.4	13.8	15.1	2.2	1.8	2.6
Uttarakhand	Female	10.2	8.9	11.6	7.7	6.7	8.8	1.7	1.3	2.3
Uttarakhand	Male	25.9	23.3	28.5	20.6	18.4	23.0	4.3	3.4	5.4
West Bengal	Female	10.1	9.6	10.6	5.7	5.3	6.0	1.8	1.5	2.0
West Bengal	Male	25.2	24.4	26.1	18.7	18.0	19.4	4.2	3.8	4.6

Abbreviations: CI=95% confidence interval

[1] Harvard-NHANES and Framingham estimates are for those aged 30 to 74 years, while Globorisk estimates are for those aged 40 to 74 years.

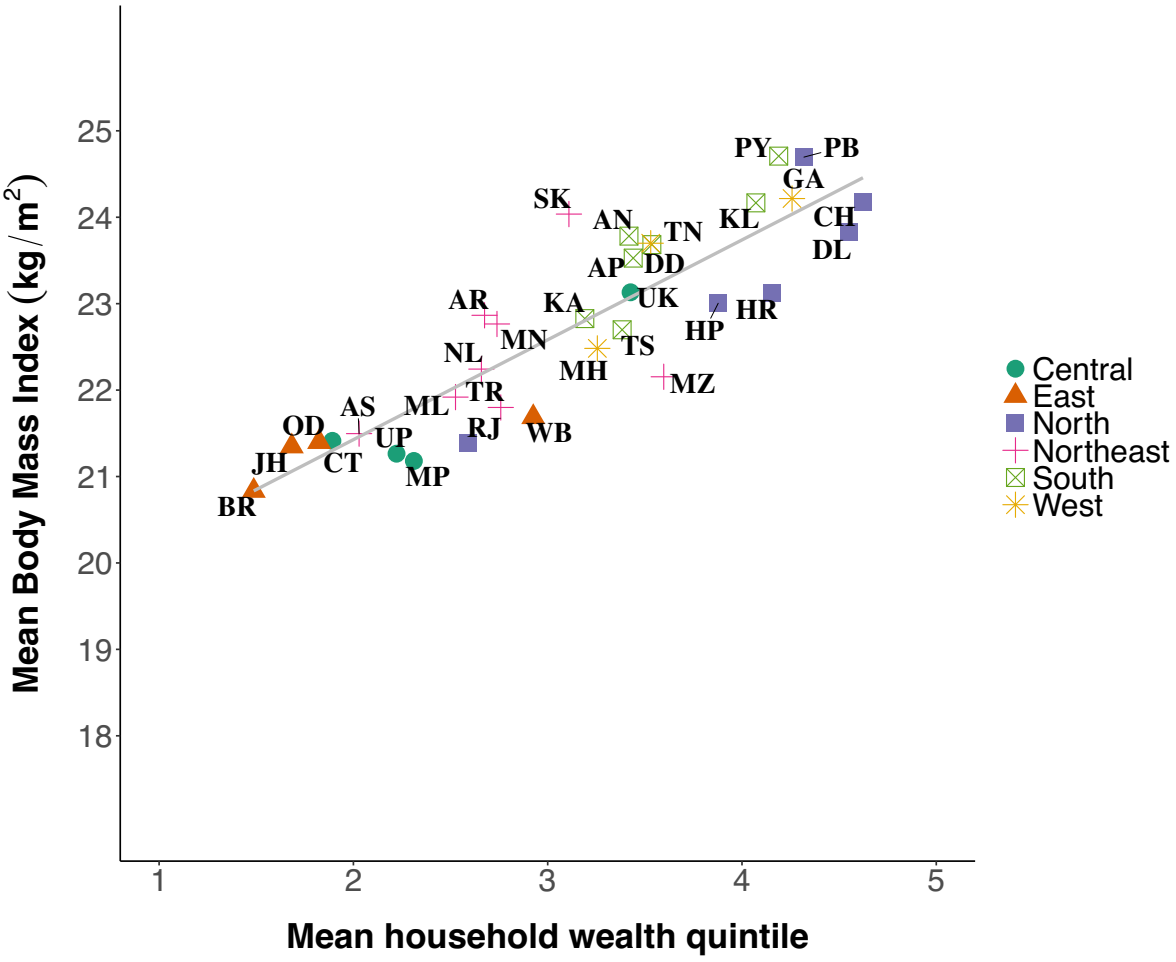
eTable18. Prevalence of cardiovascular risk factors, by state and sex

State	Sex	Mean BMI (kg/m^2)			Diabetes prevalence (%)			Mean systolic BP (mmHg)			Smoking prevalence (%)		
		Estimate	*Lower CI*	*Upper CI*	*Estimate*	*Lower CI*	*Upper CI*	*Estimate*	*Lower CI*	*Upper CI*	*Estimate*	*Lower CI*	*Upper CI*
Andaman and Nicobar	Female	23.8	23.4	24.2	11.1	9.0	13.4	128.8	126.9	130.8	2.7	1.7	3.9
Andaman and Nicobar	Male	23.7	23.4	24.1	12.1	9.9	14.4	132.0	130.3	133.7	24.6	21.1	28.3
Andhra Pradesh	Female	23.5	23.4	23.7	13.0	12.2	13.9	125.5	125.0	126.0	3.4	2.7	4.2
Andhra Pradesh	Male	23.5	23.4	23.7	14.3	13.4	15.2	128.8	128.3	129.3	30.2	28.6	31.9
Arunachal Pradesh	Female	23.0	22.8	23.2	6.4	5.1	8.0	125.2	124.1	126.4	8.5	7.3	9.7
Arunachal Pradesh	Male	22.7	22.6	22.9	6.2	4.7	7.8	127.0	126.1	127.9	46.4	43.9	48.9
Assam	Female	21.5	21.2	21.7	5.0	4.3	5.7	123.7	122.7	124.7	1.3	1.1	1.5
Assam	Male	21.5	21.3	21.8	6.1	5.2	7.0	128.1	127.2	128.9	29.4	26.3	32.6
Bihar	Female	21.0	20.8	21.2	3.2	2.7	3.7	123.6	122.6	124.6	2.7	2.1	3.3
Bihar	Male	20.6	20.5	20.8	4.3	3.7	5.0	125.2	124.5	125.9	22.5	20.4	24.7
Chandigarh	Female	24.5	24.1	24.8	15.0	12.2	18.0	129.1	127.6	130.7	0.3	0.1	0.6
Chandigarh	Male	23.9	23.5	24.2	14.6	12.2	17.2	133.8	132.5	135.0	18.7	13.2	24.9
Chhattisgarh	Female	21.2	21.0	21.4	5.0	4.2	5.8	123.4	122.3	124.5	0.4	0.3	0.6
Chhattisgarh	Male	21.6	21.4	21.8	7.2	6.0	8.5	127.0	126.1	127.8	15.1	13.0	17.3
Daman and Diu	Female	23.5	22.7	24.3	14.8	10.2	20.1	130.2	127.9	132.4	0.1	0.0	0.3
Daman and Diu	Male	24.1	23.4	24.7	10.5	6.3	15.6	132.3	130.2	134.5	9.9	6.2	14.4
Goa	Female	24.4	24.0	24.8	21.9	19.4	24.4	128.4	126.9	129.8	2.2	1.2	3.4
Goa	Male	24.0	23.7	24.3	24.8	22.0	27.7	131.4	129.6	133.2	9.3	7.1	11.8
Haryana	Female	23.3	23.2	23.4	8.1	7.6	8.6	123.7	123.3	124.0	2.2	1.9	2.5
Haryana	Male	23.0	22.9	23.1	8.3	7.8	8.9	127.6	127.3	128.0	35.3	34.0	36.6
Himachal Pradesh	Female	23.0	22.8	23.2	4.8	4.1	5.5	130.3	129.6	131.0	2.5	1.9	3.1
Himachal Pradesh	Male	23.0	22.9	23.2	4.4	3.8	5.1	132.7	132.0	133.5	41.7	39.1	44.3
Jharkhand	Female	21.2	20.9	21.5	4.5	3.8	5.3	122.3	121.5	123.2	0.7	0.4	1.0
Jharkhand	Male	21.6	21.4	21.8	5.9	5.0	6.9	126.6	125.6	127.6	9.9	8.2	11.7
Karnataka	Female	22.8	22.7	22.9	12.9	12.4	13.4	126.8	126.5	127.1	0.9	0.8	1.0
Karnataka	Male	22.9	22.8	22.9	13.8	13.2	14.4	128.6	128.3	128.9	21.4	20.5	22.2
Kerala	Female	24.4	24.2	24.6	15.1	14.0	16.1	129.6	128.7	130.5	0.8	0.6	1.1
Kerala	Male	23.9	23.7	24.2	18.3	16.9	19.8	132.3	131.2	133.4	30.4	28.2	32.7
Madhya Pradesh	Female	21.3	21.2	21.5	3.5	2.9	4.1	123.9	122.8	125.1	0.9	0.4	1.7
Madhya Pradesh	Male	21.1	20.9	21.2	4.0	3.5	4.5	126.2	125.5	126.9	25.4	23.8	27.0

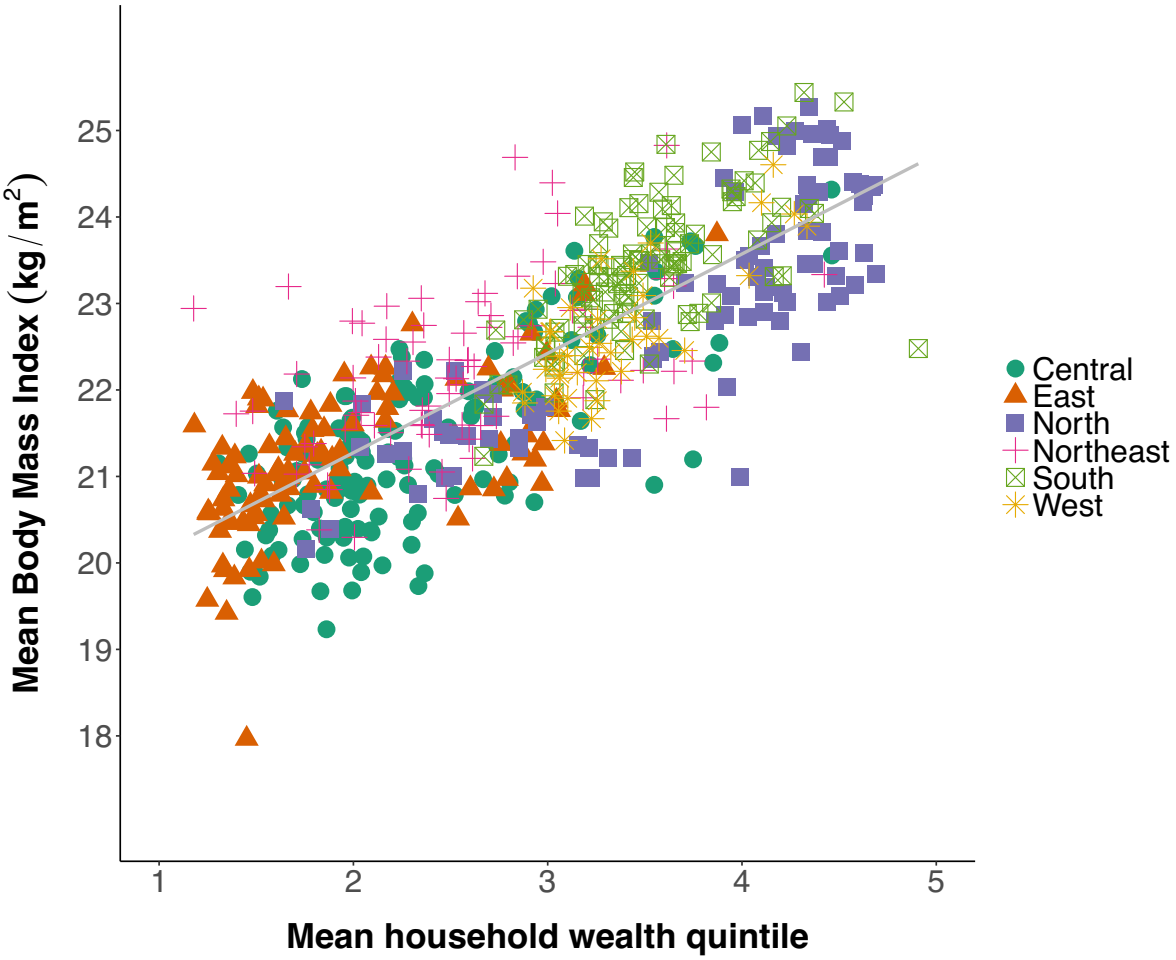
Maharashtra	Female	22.3	22.2	22.4	7.4	7.0	7.8	123.7	123.4	123.9	0.5	0.4	0.6
Maharashtra	Male	22.7	22.6	22.8	8.3	7.8	8.7	126.2	126.0	126.5	9.4	8.8	10.0
Manipur	Female	22.9	22.8	23.1	9.6	8.7	10.5	123.5	122.9	124.1	12.6	10.8	14.5
Manipur	Male	22.6	22.4	22.7	10.2	9.3	11.2	128.1	127.5	128.7	60.3	57.9	62.7
Meghalaya	Female	21.8	21.6	22.0	3.8	3.0	4.7	125.2	124.3	126.1	5.8	4.7	7.1
Meghalaya	Male	22.1	21.9	22.3	4.3	3.3	5.4	127.7	126.5	128.9	59.7	56.2	63.3
Mizoram	Female	22.1	21.9	22.2	4.6	4.0	5.3	119.1	118.5	119.6	26.1	24.5	27.6
Mizoram	Male	22.3	22.1	22.4	4.8	4.2	5.5	125.7	125.2	126.3	71.7	70.1	73.2
Nagaland	Female	22.2	22.0	22.4	7.1	6.1	8.1	130.7	129.8	131.7	1.4	1.0	1.9
Nagaland	Male	22.3	22.1	22.5	7.5	6.6	8.5	133.6	132.6	134.5	42.1	39.6	44.6
NCT of Delhi	Female	24.0	23.7	24.2	15.3	14.0	16.7	124.8	124.2	125.4	1.8	1.3	2.4
NCT of Delhi	Male	23.7	23.6	23.9	14.4	13.3	15.6	127.1	126.6	127.7	27.8	25.6	30.0
Odisha	Female	21.4	21.2	21.6	4.2	3.9	4.7	120.0	119.2	120.9	0.9	0.7	1.1
Odisha	Male	21.4	21.2	21.6	5.6	5.1	6.2	121.7	120.7	122.6	19.6	18.1	21.1
Puducherry	Female	25.1	24.8	25.4	20.7	19.1	22.3	123.9	123.3	124.6	0.3	0.1	0.5
Puducherry	Male	24.2	23.9	24.4	22.2	20.5	24.1	128.2	127.3	129.1	14.0	12.1	16.0
Punjab	Female	25.1	25.0	25.1	10.9	10.4	11.3	131.2	130.9	131.5	0.3	0.2	0.4
Punjab	Male	24.3	24.2	24.4	10.4	9.9	10.9	136.2	135.9	136.6	15.9	15.0	16.8
Rajasthan	Female	21.5	21.3	21.7	3.7	3.3	4.2	121.4	120.8	122.1	2.2	1.6	2.8
Rajasthan	Male	21.3	21.1	21.5	4.5	3.9	5.0	126.1	125.4	126.7	23.6	20.9	26.5
Sikkim	Female	24.5	24.2	24.8	7.5	6.4	8.6	132.8	131.5	134.0	6.0	4.9	7.2
Sikkim	Male	23.6	23.3	23.8	7.4	6.4	8.6	133.1	132.0	134.2	23.6	21.2	26.1
Tamil Nadu	Female	24.0	23.9	24.2	20.1	19.5	20.7	124.3	124.0	124.6	0.5	0.4	0.5
Tamil Nadu	Male	23.3	23.2	23.3	21.2	20.6	21.8	128.3	128.1	128.6	19.4	18.6	20.2
Telangana	Female	22.4	22.2	22.7	9.9	9.0	10.9	122.3	121.6	122.9	2.9	2.2	3.6
Telangana	Male	22.9	22.7	23.1	11.3	10.3	12.4	125.2	124.5	125.9	34.7	32.5	37.0
Tripura	Female	21.8	21.6	22.1	14.8	12.8	17.0	125.7	124.5	126.9	5.6	3.9	7.6
Tripura	Male	21.8	21.5	22.0	15.7	13.4	18.2	127.1	125.8	128.4	39.3	34.8	43.9
Uttar Pradesh	Female	21.7	21.5	21.8	4.7	4.2	5.2	122.9	122.1	123.6	2.5	2.1	2.9
Uttar Pradesh	Male	20.8	20.6	21.0	5.2	4.6	5.8	125.0	124.1	125.9	32.9	31.0	34.7
Uttarakhand	Female	23.4	22.9	23.8	6.3	4.7	8.0	125.8	124.5	127.2	1.6	1.1	2.3
Uttarakhand	Male	22.8	22.5	23.1	6.9	5.4	8.6	131.7	130.3	133.2	26.6	22.6	30.9
West Bengal	Female	21.7	21.6	21.8	11.6	10.9	12.4	127.0	126.4	127.5	3.3	2.8	3.9
West Bengal	Male	21.7	21.6	21.8	12.8	12.0	13.6	126.9	126.4	127.5	49.5	48.0	51.0

Abbreviations: CI=95% confidence interval

eFigure19. Association between mean Body Mass Index and household wealth quintile at the state and district level[1,2,3,4,5]

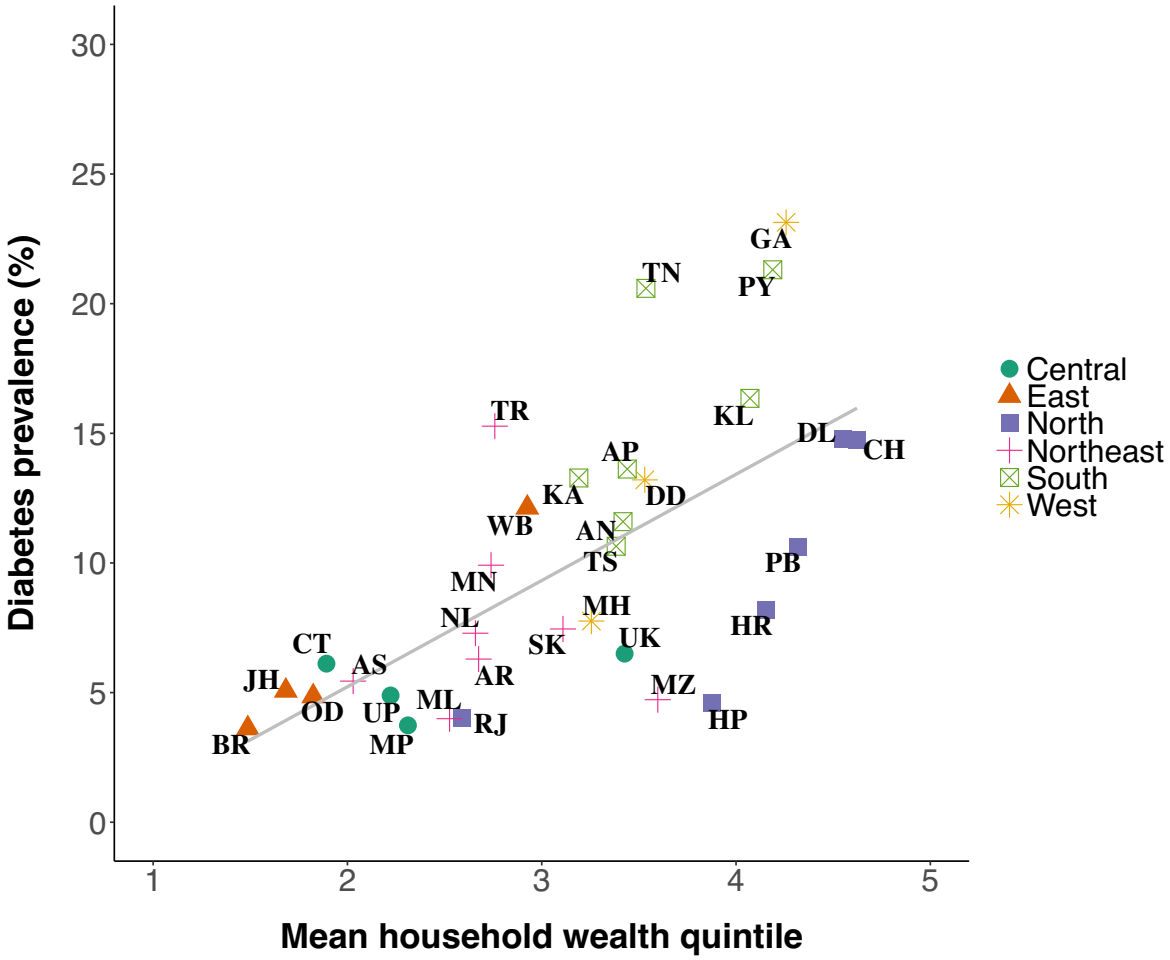


[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Mean Body Mass Index has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was <0.0001.
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CH, Chandigarh; CT, Chhattisgarh; DD, Daman and Diu; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; PY, Puducherry; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.



[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Mean Body Mass Index has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was <0.0001.
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.

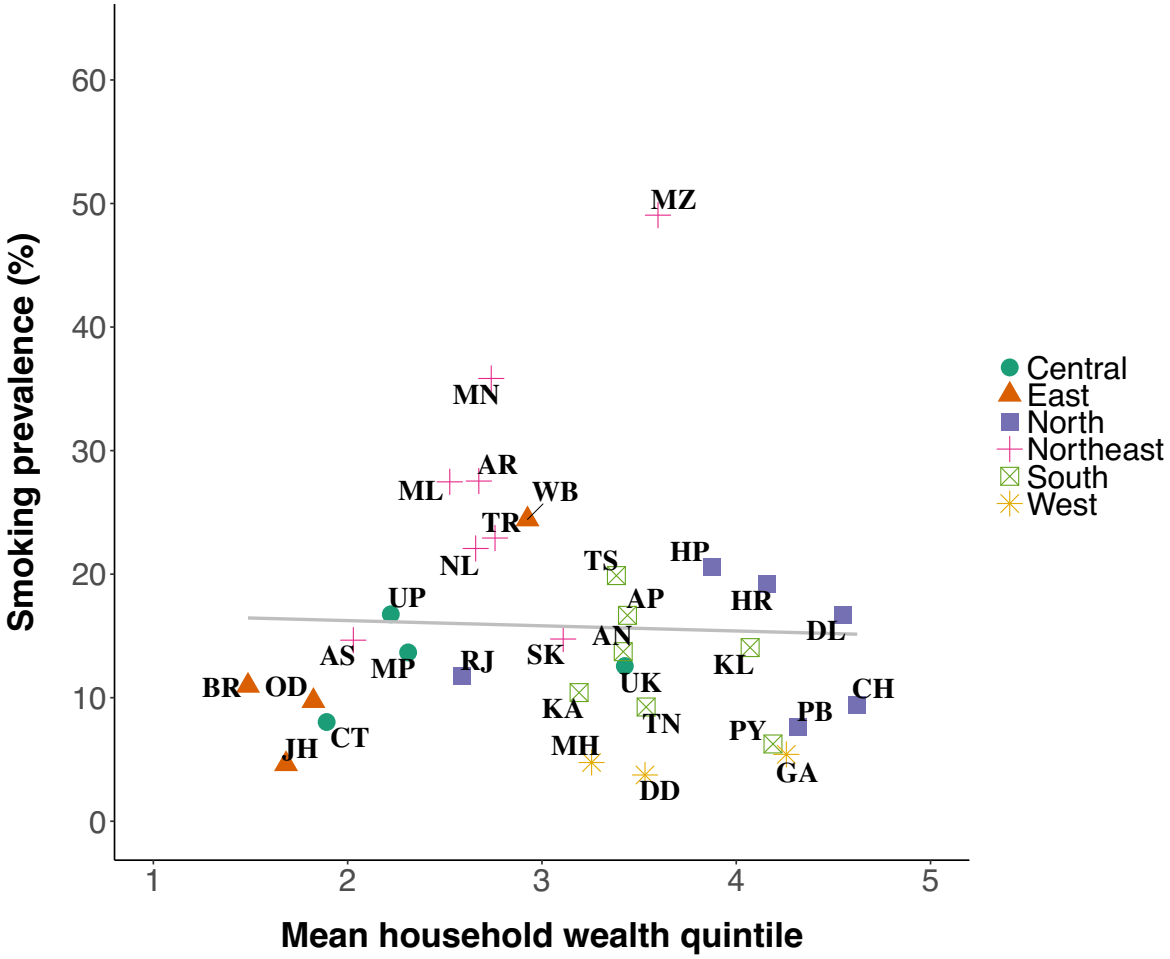
eFigure20. Association between diabetes prevalence and household wealth quintile at the state and district level[1,2,3,4,5]



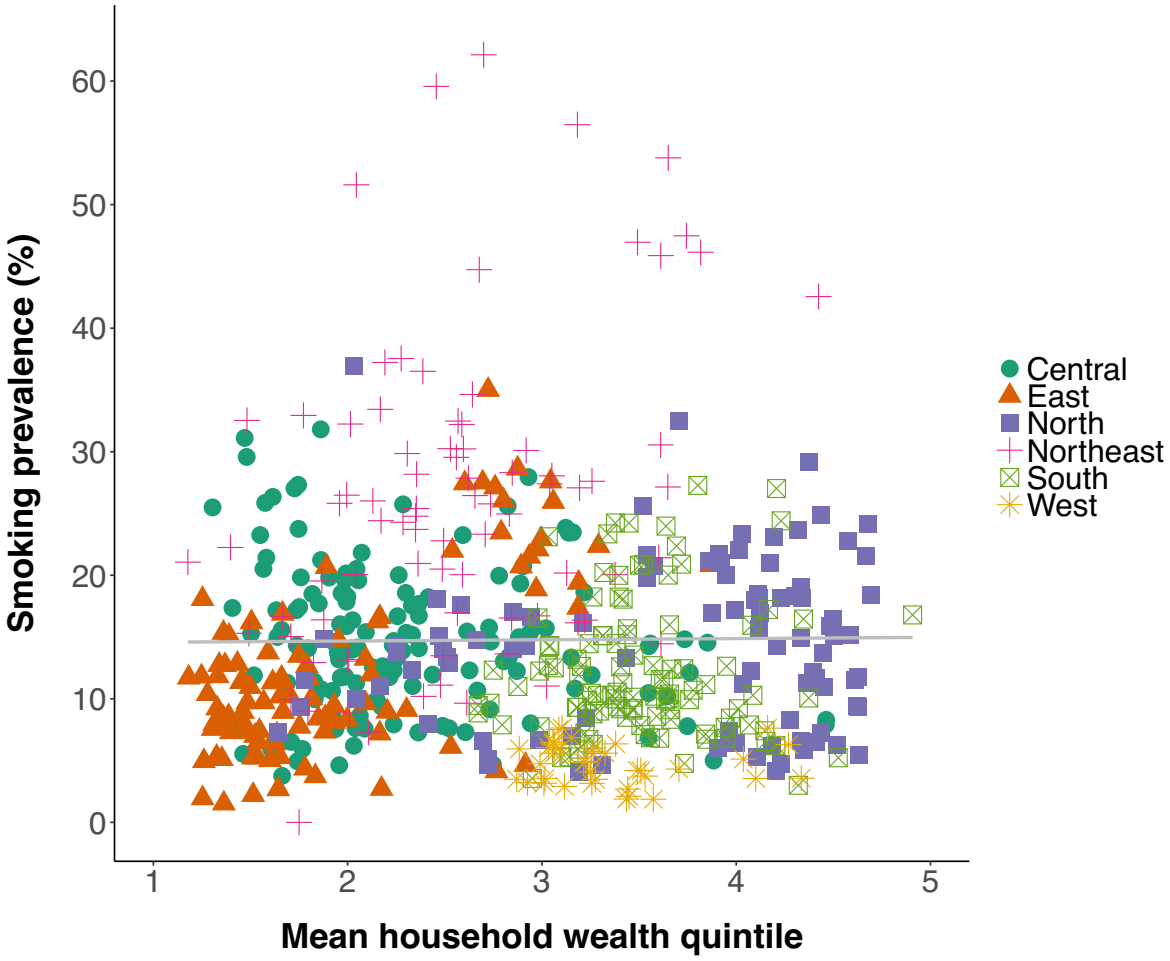
[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Diabetes prevalence has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was <0.0001
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CH, Chandigarh; CT, Chhattisgarh; DD, Daman and Diu; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; PY, Puducherry; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Diabetes prevalence has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was <0.0001.
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.

eFigure21. Association between smoking prevalence and household wealth quintile at the state and district level[1,2,3,4,5]

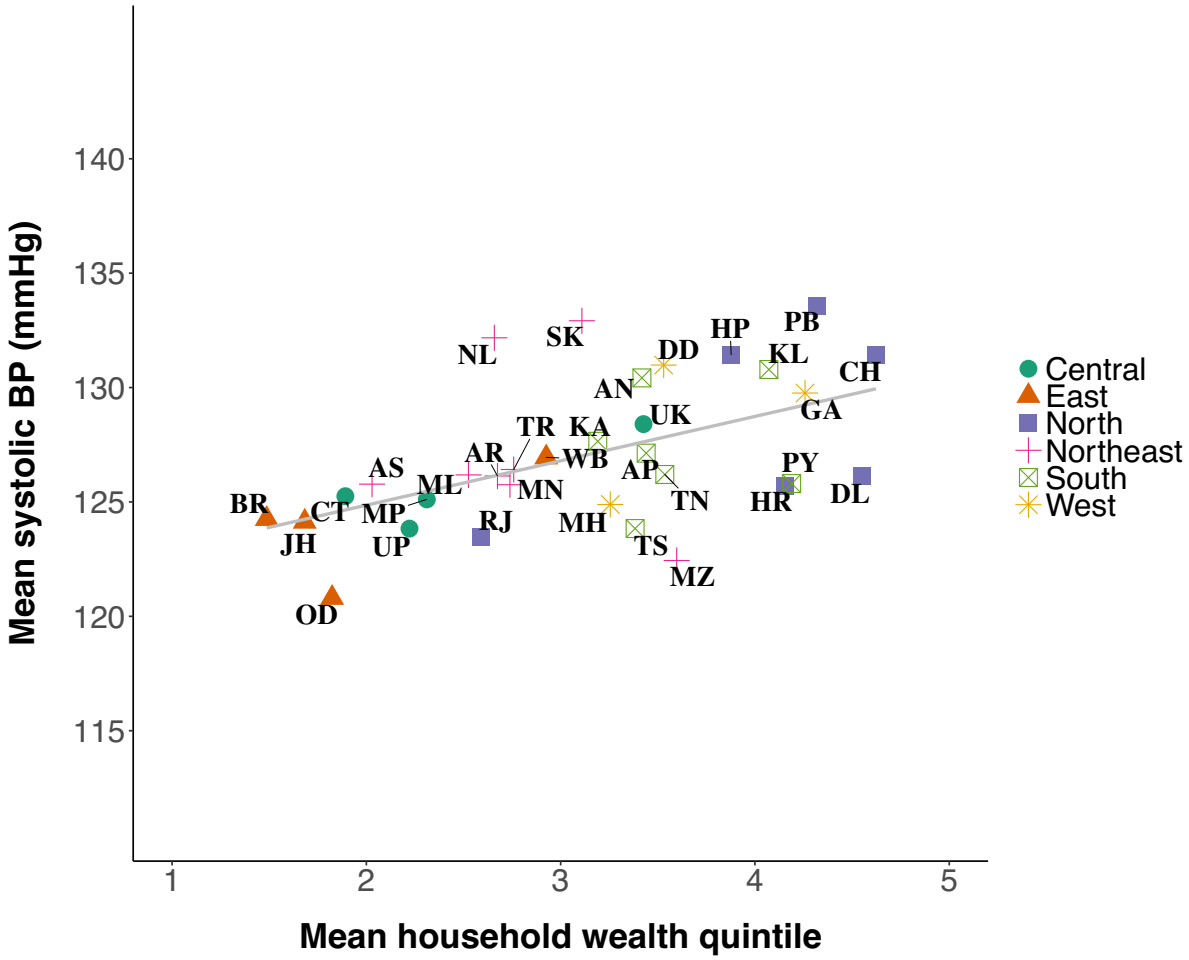


[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Smoking prevalence has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was 0.84.
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CH, Chandigarh; CT, Chhattisgarh; DD, Daman and Diu; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; PY, Puducherry; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

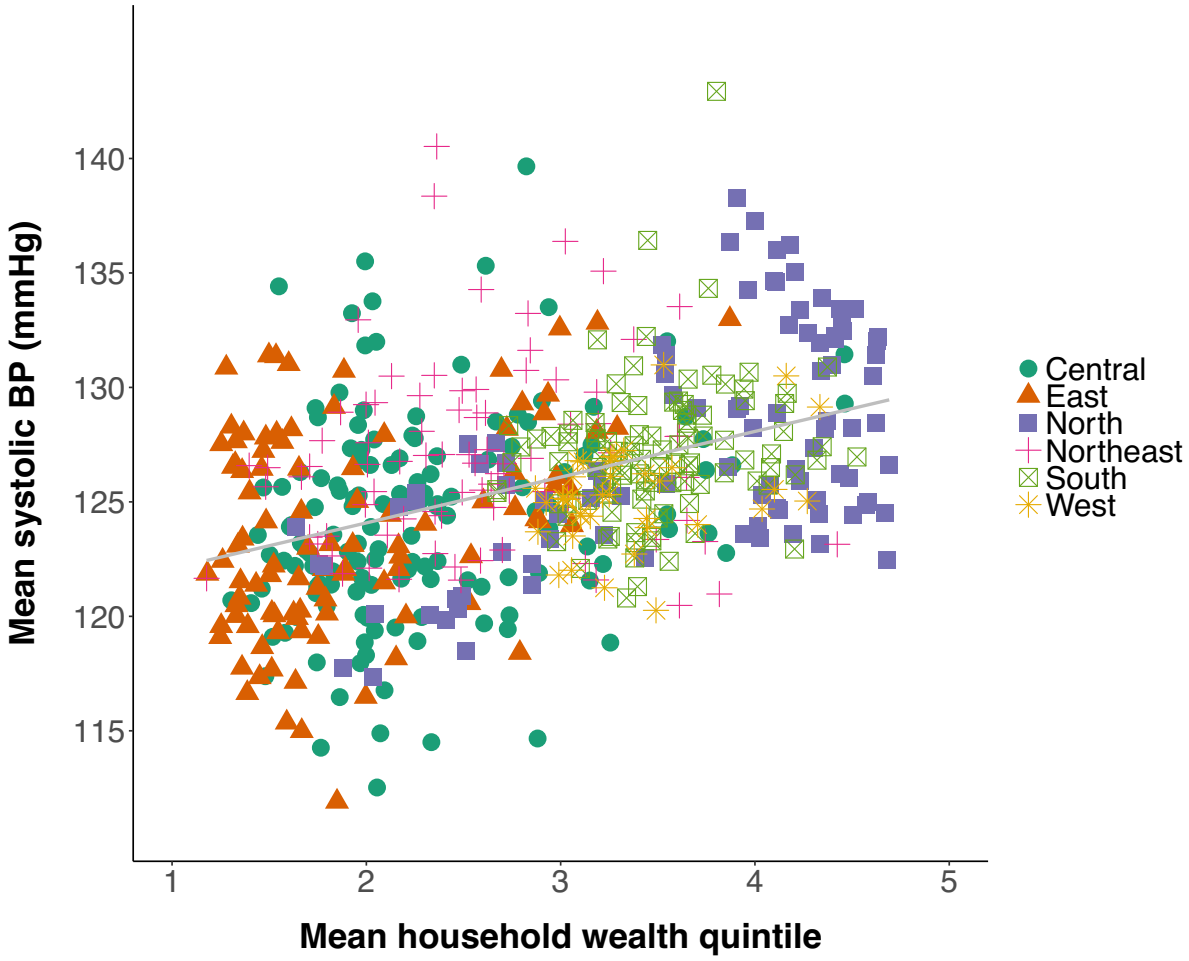


[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Smoking prevalence has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was 0.81.
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.

eFigure22. Association between mean systolic blood pressure and household wealth quintile at the state and district level[1,2,3,4,5]

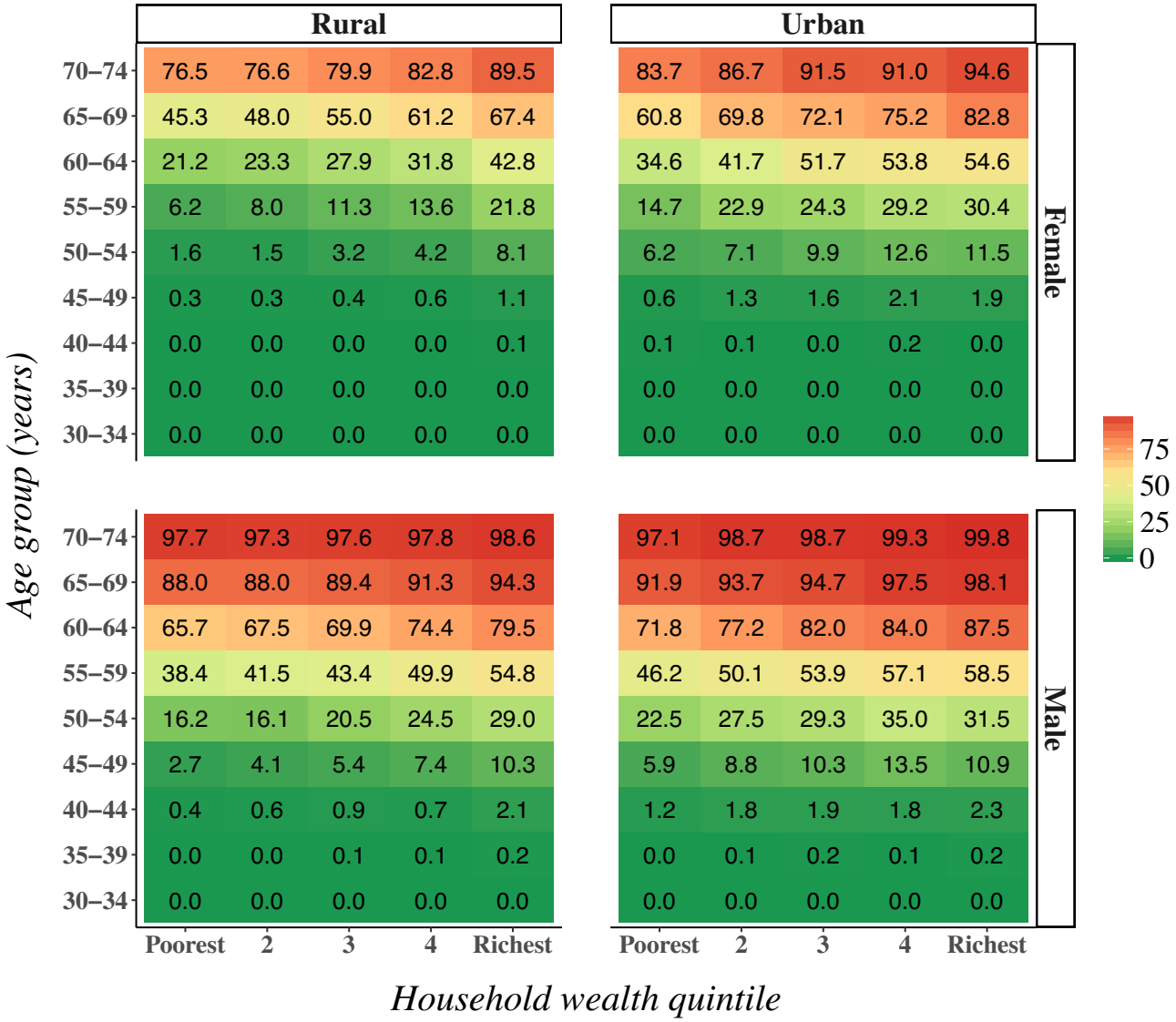


[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Mean systolic blood pressure has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was 0.002.
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.
Abbreviations: AP, Andhra Pradesh; AR, Arunachal Pradesh; AS, Assam; BR, Bihar; CH, Chandigarh; CT, Chhattisgarh; DD, Daman and Diu; DL, Delhi; GA, Goa; GJ, Gujarat; HR, Haryana; HP, Himachal Pradesh; JK, Jammu & Kashmir; JH, Jharkhand; KA, Karnataka; KL, Kerala; MP, Madhya Pradesh; MH, Maharashtra; MN, Manipur; ML, Meghalaya; MZ, Mizoram; NL, Nagaland; OD, Odisha (Orissa); PB, Punjab; PY, Puducherry; RJ, Rajasthan; SK, Sikkim; TN, Tamil Nadu; TS, Telangana State; TR, Tripura; UP, Uttar Pradesh; UK, Uttarakhand (Uttaranchal); WB, West Bengal.

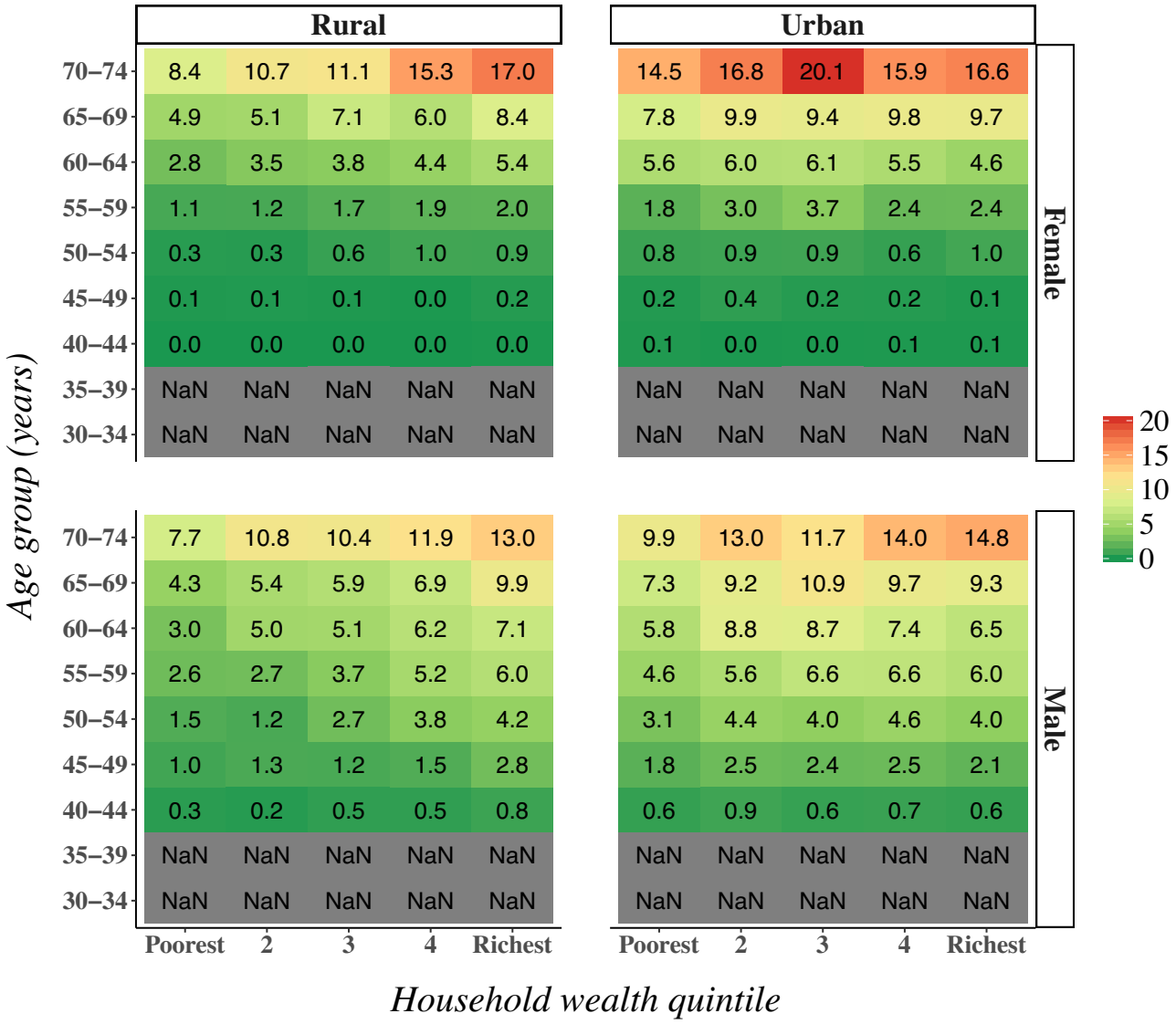


[1] Standard of living was measured by the mean household wealth quintile in a state/district, whereby household wealth quintile was computed at the national level (and not separately for rural and urban areas).
[2] Mean systolic blood pressure has been age-standardised to the Global Burden of Disease project's 2013 population structure for India.[114]
[3] The p-value for the statistical significance of the linear (ordinary least squares) regression line (shown in grey) was <0.0001.
[4] States and districts were divided into regions as per their allocation to Zonal Councils by the Government of India.[92]
[5] The sample in each state and district has been restricted to those aged 30 to 74 years.

eFigure23. Percentage of population with a high (≥30%) 10-year Harvard-NHANES score by household wealth quintile, age group, rural versus urban location, and sex.

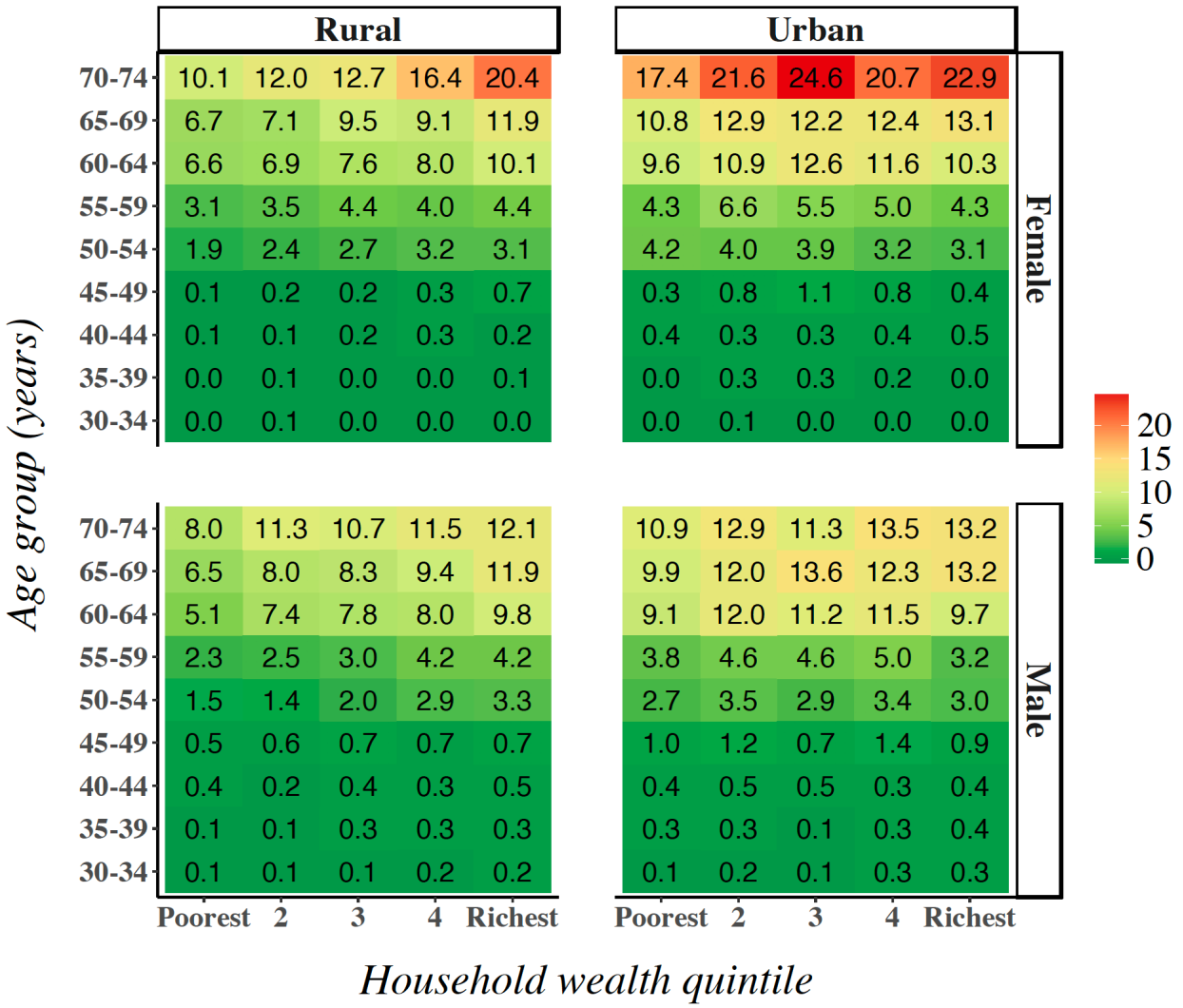


eFigure24. Percentage of population with a high (≥30%) 10-year Globorisk score by household wealth quintile, age group, rural versus urban location, and sex.[1]



[1] Globorisk estimates cardiovascular risk only for those aged 40 to 74 years.

eFigure25. Percentage of population with a high (≥30%) 10-year WHO-ISH score by household wealth quintile, age group, rural versus urban location, and sex.



eTable19. Ordinary least squares regressions of the natural logarithm of the Harvard-NHANES risk score on sociodemographic covariates and PSU-level fixed effects[1]

	Female (n=420,691)				Male (n=376,849)			
	Adjusted for age group only[2]		Adjusted for all covariates[3]		Adjusted for age group only[2]		Adjusted for all covariates[3]	
	Coefficient[4] (95% CI)	*P*	*Coefficient[4] (95% CI)*	*P*	*Coefficient[4] (95% CI)*	*P*	*Coefficient[4] (95% CI)*	*P*
Wealth quintile								
1 (poorest)	Ref.		Ref.		Ref.		Ref.	
2	3.16 (2.78, 3.55)	<0.001	2.77 (2.39, 3.15)	<0.001	1.30 (0.90, 1.71)	<0.001	1.13 (0.72, 1.54)	<0.001
3	6.22 (5.81, 6.62)	<0.001	5.86 (5.45, 6.27)	<0.001	2.88 (2.45, 3.31)	<0.001	2.84 (2.40, 3.27)	<0.001
4	10.21 (9.80, 10.62)	<0.001	9.63 (9.20, 10.05)	<0.001	5.02 (4.58, 5.46)	<0.001	4.90 (4.44, 5.35)	<0.001
5 (richest)	17.54 (17.12, 17.96)	<0.001	16.55 (16.10, 17.00)	<0.001	9.61 (9.16, 10.05)	<0.001	9.26 (8.78, 9.75)	<0.001
Educational attainment								
<Primary School	Ref.		Ref.		Ref.		Ref.	
Primary School	7.00 (6.62, 7.37)	<0.001	4.31 (3.93, 4.69)	<0.001	2.29 (1.89, 2.69)	<0.001	1.26 (0.87, 1.66)	<0.001
Middle School	8.45 (8.06, 8.83)	<0.001	4.53 (4.14, 4.92)	<0.001	3.58 (3.20, 3.96)	<0.001	1.87 (1.48, 2.25)	<0.001
Secondary School	11.53 (11.11, 11.96)	<0.001	5.41 (4.97, 5.85)	<0.001	5.42 (5.03, 5.80)	<0.001	2.51 (2.10, 2.91)	<0.001
High School	11.01 (10.43, 11.59)	<0.001	3.70 (3.11, 4.29)	<0.001	4.45 (3.97, 4.93)	<0.001	0.89 (0.39, 1.39)	<0.001
>High School	11.15 (10.59, 11.71)	<0.001	1.44 (0.84, 2.03)	<0.001	7.23 (6.78, 7.67)	<0.001	2.15 (1.66, 2.63)	<0.001
Geography								
Rural	Ref.		Ref.		Ref.		Ref.	
Urban	12.35 (11.89, 12.81)	<0.001	12.78 (12.30, 13.26)	<0.001	8.65 (8.16, 9.13)	<0.001	9.02 (8.52, 9.51)	<0.001

Abbreviations: CI=Confidence Interval; Ref. = Reference category.

[1] Standard errors were adjusted for clustering at the household level.

[2] These models included one sociodemographic characteristic, age group, and a binary indicator variable for each primary sampling unit (PSU) as explanatory variables.

[3] This model included all variables listed in the table, age group, and a binary indicator for each PSU as explanatory variables.

[4] Coefficients were multiplied by 100 so that they can be interpreted more easily as an approximation of the percentage change in cardiovascular risk associated with a one unit change in the explanatory variable.

eTable20. Ordinary least squares regressions of the natural logarithm of the Globorisk score on sociodemographic covariates and PSU-level fixed effects[1]

	Female (n=276,467)				Male (n=261,954)			
	Adjusted for age group only[2]		Adjusted for all covariates[3]		Adjusted for age group only[2]		Adjusted for all covariates[3]	
	Coefficient[4] *(95% CI)*	*P*	*Coefficient*[4] *(95% CI)*	*P*	*Coefficient*[4] *(95% CI)*	*P*	*Coefficient*[4] *(95% CI)*	*P*
Wealth quintile								
1 (poorest)	Ref.		Ref.		Ref.		Ref.	
2	2.01 (1.44 - 2.57)	<0.001	1.61 (1.05 - 2.18)	<0.001	1.58 (1.00 – 2.15)	<0.001	1.37 (0.79 - 1.94)	<0.001
3	4.30 (3.71 - 4.90)	<0.001	3.75 (3.15 - 4.35)	<0.001	3.01 (2.40 – 3.61)	<0.001	2.79 (2.18 - 3.41	<0.001
4	7.18 (6.57 - 7.78)	<0.001	6.25 (5.63 – 6.87)	<0.001	5.03 (4.41 – 5.64)	<0.001	4.68 (4.04 - 5.32)	<0.001
5 (richest)	14.25 (13.64 - 14.86)	<0.001	12.62 (11.97 – 13.27)	<0.001	10.56 (9.94 – 11.18)	<0.001	9.89 (9.22 – 10.57)	<0.001
Educational attainment								
<Primary School	Ref.		Ref.		Ref.		Ref.	
Primary School	6.55 (6.00 - 7.10)	<0.001	4.28 (3.72 - 4.84)	<0.001	2.25 (1.71 – 2.79)	<0.001	1.23 (0.69 - 1.78)	<0.001
Middle School	7.83 (7.23 – 8.42)	<0.001	4.63 (4.02 - 5.24)	<0.001	3.45 (2.92 - 3.99)	<0.001	1.78 (1.24 – 2.32)	<0.001
Secondary School	10.76 (10.09 - 11.43)	<0.001	5.77 (5.06 - 6.47)	<0.001	5.79 (5.25 - 6.33)	<0.001	2.84 (2.28 - 3.41)	<0.001
High School	10.73 (9.73 - 11.73)	<0.001	5.11 (4.09 – 6.14)	<0.001	3.94 (3.24 – 4.65)	<0.001	0.47 (-0.27 - 1.20)	0.216
>High School	10.29 (9.35 – 11.23)	<0.001	2.95 (1.97 - 3.94)	<0.001	7.00 (6.37 – 7.64)	<0.001	2.12 (1.42 - 2.81)	<0.001
Geography								
Rural	Ref.		Ref.		Ref.		Ref.	
Urban	9.40 (8.73 – 10.08)	<0.001	8.84 (8.14 – 9.54)	<0.001	5.93 (5.25 – 6.61)	<0.001	6.10 (5.40 – 6.80)	<0.001

Abbreviations: CI=Confidence Interval; Ref. = Reference category.

[1] Standard errors were adjusted for clustering at the household level.

[2] These models included one sociodemographic characteristic, age group, and a binary indicator variable for each primary sampling unit (PSU) as explanatory variables.

[3] This model included all variables listed in the table, age group, and a binary indicator for each PSU as explanatory variables.

[4] Coefficients were multiplied by 100 so that they can be interpreted more easily as an approximation of the percentage change in cardiovascular risk associated with a one unit change in the explanatory variable.

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